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DETAILED ANALYSIS OF ALTERNATIVES REPORT SITE 09 - ALLEN HARBOR LANDFILL

NAVAL CONSTRUCTION BATTALION CENTER DAVISVILLE, RHODE ISLAND

Contract No. N62472-86-C-1282
March, 1994

Prepared For:
Northern Division
Naval Facilities Engineering Command
Lester, Pennsylvania

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APPENDICES

EXECUTIVE SUMMARY

At the request of the U.S. Navy, TRC Environmental Corporation (TRC) has prepared this Detailed Analysis of Alternatives (DAA) Report for Site 09 - Allen Harbor Landfill, at the Naval Construction Battalion Center in Davisville, Rhode Island (NCBC Davisville). The DAA is part of the Feasibility Study (FS) process and is being conducted under the Navy's Installation Restoration Program and in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA).

Introduction

Twelve sites at the NCBC facility are being investigated under a Remedial Investigation/Feasibility Study (RI/FS) program. Phase I and Phase II Remedial Investigations (RIs) have been conducted to investigate the physical characteristics of the sites, as well as to identify potential sources of contamination, determine the nature and extent of contamination, and characterize potential health risks and environmental impacts. Detailed site background information, results of the investigations, and a characterization of the potential risks to human health and the environment posed by the sites are presented within several separate Remedial Investigation Reports (TRC, 1993d, 1993e, and 1993f). Initial screenings of potential remedial alternatives were also conducted for the sites within two Initial Screening of Alternatives (ISA) Reports (TRC, 1993a, 1993b). This DAA Report, which addresses only Site 09 - Allen Harbor Landfill, builds upon the analysis conducted within the (ISA) report, presenting remedial alternatives developed based on the results of the Phase I and Phase II RIs, and detailed analyses of those alternatives.

Background

Site 09 - Allen Harbor Landfill covers an area of approximately 13.5 acres on the western side of Allen Harbor. A general site map is provided in Figure ES-1. The landfill is bounded to the east and south by Allen Harbor, and to the west by Sanford Road. A marsh is located to the west of the landfill, on the opposite side of Sanford Road. A fence runs along the west side of Sanford Road, at the edge of Navy property. Access to the landfill is controlled by a fence and a locked gate at the Sanford Road entrance.

Allen Harbor is currently overgrown with a mixture of shrubs, small trees, and grasses. The only extensive areas of stressed vegetation appear to be the locations of former pavement and/or access roads. Substantial amounts of building demolition debris and rusted metallic objects are visible at various locations across the landfill surface. The landfill rises approximately 15 to 20 feet above the high tide mark along its southeastern perimeter. Large pieces of demolition debris, including significant amounts of structural steel, are visible along the nearly vertical face of the landfill toe.

From 1946 to 1972, the site was used as a landfill for wastes generated at NCBC Davisville and the former NAS Quonset Point. A variety of wastes, including preservatives, paint thinners, degreasers, PCBs, asbestos, ash, sewage sludge, and contaminated fuel oil were reportedly disposed of in the landfill, usually by burning and then covering.

Site investigations have consisted of an Initial Assessment Study (Hart, 1984a), a Confirmation Study (TRC, 1987), the Phase I RI (TRC, 1991), and the Phase II RI (TRC, 1993e).

Based on the results of site investigations, the nature and extent of site contamination were defined, as were potential risks to human health and the environment. Surface soil contamination and sediment contamination at the toe of the landfill present potential risks to human health and the environment. While ground water contamination was detected, ingestion of ground water is not anticipated to be a potential exposure pathway, based on the site's proximity to Allen Harbor and the probable brackish quality of the ground water. Discharge of leachate seeps provides a potential contamination migration route which could impact sediments at the toe of the landfill. Ground water migration to Allen Harbor and surrounding wetlands is also a potential contaminant migration pathway. However, ecological assessments of Allen Harbor have not identified significant ecological risks attributable to the landfill. Therefore, while Ambient Water Quality Criteria (AWQC) are used within the DAA as a basis for evaluating ground water remediation options, modification of these criteria before direct application to ground water quality is appropriate.

Feasibility Study Process

The first step of the Feasibility Study process, the ISA, was conducted for Site 09 on the basis of Phase I RI information only. The ISA report included the development of remedial action objectives, the screening of potential remedial technologies and process options, and the development and initial screening of remedial alternatives. This report incorporates the results of the Phase II RI, and presents the refinement of remedial response objectives, the refinement of remedial alternatives, and detailed individual and comparative analyses of the remedial alternatives.

Key to the development of remedial alternatives for remedial actions at a landfill site is the consideration of U.S. EPA's expectations for remediation of such sites under the Superfund program. These expectations are listed in the National Contingency Plan [40 CFR 300.430(a)(1)] and in U.S. EPA's guidance on Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites (U.S. EPA, 1991a), where they are outlined as follows:

- The principal threats posed by a site should be treated wherever practicable, such as in the case of remediation of a hot spot.
- Engineering controls, such as containment, will be used for waste that poses a relatively low long-term threat or where treatment is impracticable.
- A combination of methods will be used as appropriate to achieve protection of human health and the environment. An example of combined methods for a landfill site would be treatment of hot spots in conjunction with containment (capping) of the landfill contents.
- Institutional controls, such as deed restrictions, will be used to supplement engineering controls, as appropriate, to prevent exposure to hazardous wastes.
- Innovative technologies will be considered when such technologies offer the potential for superior treatment performance or lower costs for performance similar to that of demonstrated technologies.
- Ground water will be returned to beneficial uses whenever practical, within a reasonable time, given the particular circumstances of the site.

These expectations were used to guide the development of remedial action objectives and remedial alternatives for the Allen Harbor Landfill site.

Feasibility Study Summary

Based on the nature and extent of contamination at Site 09 as well as the potential human health and ecological risks posed by the site, Remedial Action Objectives were developed as follows:

For soil/waste materials:

- Minimize potential risk to human health associated with exposure to surface soil contaminants, including contaminants detected at levels exceeding ARARs/TBCs, as presented in Table 3-1, and contaminants detected at levels exceeding risk-based cleanup levels, as presented in Table 3-5, as appropriate; and

- Minimize potential environmental impacts by minimizing off-site migration of surface soil contaminants.

For ground water/leachate:

- Minimize potential environmental impacts which could be associated with the migration of contaminated ground water or leachate from the landfill area via surface seeps or subsurface migration to Allen Harbor or adjacent wetland areas.

For sediment:

- Minimize potential environmental impacts associated with exposures to contaminated sediments at the toe of the landfill face to the greatest extent possible, without creating more significant adverse environmental impacts.

Remedial alternatives were developed for each of the environmental media and evaluated in detail with respect to the evaluation criteria specified in the NCP. A list of the alternatives for which detailed analyses were conducted is presented in Table ES-1.

Because interactions between media and media-specific remedial alternatives will greatly impact the selection of a final remedial alternative for Site 09, four comprehensive alternatives were also assembled for a general evaluation. Based on the remedial alternatives evaluated for the individual environmental media at Site 09, numerous comprehensive alternatives consisting of various combinations of media-specific alternatives could be developed. While it is not possible to describe and evaluate each combination of alternatives, the four general alternatives evaluated include:

- No Action
- Limited Action

- Containment
- Containment with Ground Water Treatment

A summary of the components which are included in each of the comprehensive alternatives as evaluated is presented in Table ES-2.

Alternative 1 - No Action

A comprehensive no action alternative would consist of no action with respect to soil/waste, ground water/leachate and sediment. It would not provide overall protection of human health and the environment, would not achieve remedial action objectives and would not be protective in the long-term.

Alternative 2 - Limited Action

A comprehensive limited action alternative would consist of institutional controls for soil/waste, ground water/leachate and sediment. It could consist of the following:

- Deed restrictions to limit future exposures to subsurface waste materials and contaminated ground water

- Fencing to prevent human exposures to contaminated surface materials

- Long-term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present increased ecological risks

While this alternative would be protective of human health in terms of limiting potential human exposures to site contamination, it would not ensure the long-term protection of the environment. No reduction in surficial contaminant migration, leachate seeps, potential ground water migration, or exposures of surficial contaminants to ecological receptors would be achieved. The presence of fencing and residual contamination would prohibit future recreational use of the site and could impact the value of the site as a conservation area, both preferred future site uses specified in the Base Reuse Plan.

Alternative 3 - Containment

A comprehensive containment alternative would consist of containment measures combined with institutional controls and long-term monitoring, in accordance with a RCRA hybrid closure approach. A possible containment alternative would consist of the following:

- Landfill cap consisting of a native soil cap or single-barrier cap (Alternative S/W-3B, RCRA Hybrid cap) and storm water discharge monitoring

- Containment of landfill toe sediments

- Deed restrictions to limit future exposures to subsurface waste materials and contaminated ground water, and prevent disruption of the capping system

- Long-term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present ecological risks

This alternative would provide overall protection of human health and the environment. Direct exposures to contaminated surface materials would be eliminated by the presence of the cap. The cap would also reduce the potential for leachate seeps to discharge directly to Allen Harbor, especially if the single-barrier cap was utilized. By providing sediment containment along the landfill toe, the sediment exposure pathway which has been associated with potential ecological risks would be eliminated and long-term protection of the cap against storm events would be provided. The native soil cap would be more amenable to reestablishment of existing vegetation; the single-barrier cap planted with shallow-rooted grasses would provide a meadow-type habitat. Long-term monitoring would allow for the identification of any changes in environmental quality which could result in increased ecological impacts. Implementation of this alternative would be compatible with future site use as a recreation/conservation area.

Alternative 4 - Containment With Ground Water Treatment

This comprehensive alternative consists of containment features coupled with active ground water remediation. It could consist of the following:

- RCRA hybrid (single-barrier) cap and storm water discharge monitoring

- Sheet piling vertical barrier to contain the contaminated ground water and limit the volume of contaminated ground water requiring treatment

- Ground water extraction, air stripping, and chemical precipitation with discharge to Allen Harbor

- Long-term ground water monitoring

- Deed restrictions to limit future exposures to subsurface waste materials

This alternative would also be protective of human health and the environment although the reductions in potential ecological risk associated with ground water remediation may not be justified by the costs associated with providing vertical containment and ground water treatment. Also, when the active treatment of ground water would be discontinued, re-contamination of ground water could occur. Although containment systems would be in-place to limit the accumulation of ground water within the landfill area, no containment system is totally impervious. The slow leakage of ground water through the vertical barrier and/or cap could eventually result in the re-accumulation of ground water within the waste layer in the southern portion of the site.

Comparative Evaluation of Comprehensive Alternatives

A comparison of the four comprehensive remedial alternatives described above against the alternative evaluation criteria is presented in Tables ES-3 through ES-9.

Recommendations and Conclusions

Based on the individual analyses of media-specific alternatives as well as the evaluation of the comprehensive alternatives, the recommended remedial alternative for Site 09 consists of a containment action consisting of the following:

- Landfill cap consisting of a native soil cap or single-barrier cap (Alternative S/W-3B, RCRA Hybrid cap)

- Containment of landfill toe sediments

- Deed restrictions to limit future exposures to subsurface waste materials, disruption of the capping system, and contaminated ground water

- Long-term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present ecological risks.

This alternative would be protective of human health and the environment, would be effective in the long-term, and would comply with location-specific and action-specific ARARs. Based on the lack of ecological impacts attributable to contaminated ground water migration identified during site and Allen Harbor ecological studies, the lack of ground water treatment is not expected to adversely effect the environment. Long-term monitoring would be utilized to ensure continued protection of the environment. Protection against human health and ecological risks posed by surficial contamination, leachate seeps, and sediment contamination at the toe of the landfill would be provided by the containment features of the alternative. Deed restrictions would limit the potential for future disruption of the containment systems. The alternative would complement future use of the site for recreation or conservation purposes, as specified in the Base Reuse Plan.

TABLE ES-1
SITE 09 – ALLEN HARBOR LANDFILL
ALTERNATIVES UNDERGOING DETAILED ANALYSIS

Soil/Waste	Ground Water/Leachate
Alternative S/W-1 No Action Alternative S/W-2 Limited Action (Institutional Controls) A. Fencing/Deed Restrictions Alternative S/W-3 Containment (including Grading/Revegitation) A. Native Soil Cap B. RCRA Subtitle C Hybrid Cap C. RCRA Subtitle C Landfill Cap	Alternative GW-1 No Action Alternative GW-2 Limited Action (Institutional Controls) A. Long – Term Monitoring B. Deed Restrictions Alternative GW-3 Containment A. Capping B. Sheet Piling Alternative GW-4 Treatment A. Extraction (Extraction Wells) B. Air Stripping C. UV Oxidation D. Precipitation E. Membrane Microfiltration F. Discharge to Surface Water
Sediment Alternative SD-1 No Action Alternative SD-2 Limited Action (Institutional Controls) A. Long – Term Monitoring Alternative SD-3 Containment A. Stone	

TABLE ES-2
DESCRIPTIONS OF GENERAL COMPREHENSIVE ALTERNATIVES
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 - No Action	• No action
Alternative 2 - Limited Action	• Deed restrictions to limit future exposures to subsurface waste materials and contaminated ground water • Fencing to prevent human exposures to contaminated surface materials • Long-term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present increased ecological risks
Alternative 3 - Containment	• Landfill cap consisting of a native soil cap or single-barrier cap and stormwater discharge monitoring • Containment of landfill toe sediments • Deed restrictions to limit future exposures to subsurface waste materials, disruption of the capping system and exposures to contaminated ground water • Long-term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present increased ecological risks
Alternative 4 - Containment with Ground Water Treatment	• Single-barrier cap and stormwater discharge monitoring • Sheet piling • Ground water extraction, air stripping, and chemical precipitation with discharge to Allen Harbor • Long-term ground water monitoring • Deed restrictions to limit future exposures to subsurface waste materials

TABLE ES-3
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 – No Action	Provides no overall protection of human health and the environment; Does not meet remedial action objectives; Not effective in the long-term
Alt rnative 2 – Limited Action	Provides protection of human health but not the environment; Does not address leachate seeps, potential ground water migration or potential exposures to surficial contaminants by ecological receptors; Not effective in the long-term
Alternative 3 – Containment	Protective of human health and the environment; Limits potential exposures to human receptors through physical containment and deed restrictions; Limits potential environmental impacts through physical containment of contaminated surface materials and sediments; Potential exposures and contaminant migration due to leachate seeps are minimized by presence of cap; Provides long-term monitoring to identify any potential environmental impacts due to ground water migration in the future
Alternative 4 – Containment with Ground Water Treatment	Protective of human health and the environment; Limits potential exposures to human receptors through physical containment and deed restrictions; Limits potential environmental impacts through physical containment of contaminated surface materials and sediments; Potential exposures and contaminant migration due to leachate seeps are minimized by presence of cap; Provides active treatment of ground water, thereby minimizing potential environmental impacts due to ground water migration in the future; Protection against contaminated ground water migration may not be permanent following treatment system discontinuation

TABLE ES-4
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
COMPLIANCE WITH ARARS
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE, RI

ACTION	CHEMICAL-SPECIFIC	LOCATION-SPECIFIC	ACTION-SPECIFIC
Alternative 1 – No Action	Does not meet ARARs/TBCs applicable to soil; Ambient Water Quality Criteria (AWQC) exceeded in ground water but due to lack of ecological impacts definitely attributable to ground water discharge, modification of AWQC may be appropriate before application as ground water ARARs	Meets criteria; involves no actions which impact coastal or wetland areas	Not applicable Not applicable
Alternative 2 – Limited Action	Does not meet ARARs/TBCs applicable to soil; Ambient Water Quality Criteria (AWQC) exceeded in ground water but due to lack of ecological impacts definitely attributable to ground water discharge, modification of AWQC may be appropriate before application as ground water ARARs	Construction of fencing would comply with criteria (i.e. wetland and coastal requirements)	Would comply with action-specific ARARs applicable to monitoring and construction activities
Alternative 3 – Containment	Meets ARARs/TBCs applicable to soil through containment; Ambient Water Quality Criteria (AWQC) exceeded in ground water but due to lack of ecological impacts definitely attributable to ground water discharge, modification of AWQC may be appropriate before application as ground water ARARs	Cap construction and sediment containment would comply with criteria (i.e. wetland and coastal zone requirements); Mitigation of any impacted wetlands may be required	Would comply with action-specific ARARs applicable to monitoring, construction, stormwater discharge, landfill closure, and venting (as appropriate) activities
Alternative 4 – Containment with Ground Water Treatment	Meets ARARs/TBCs applicable to soil through containment; Ambient Water Quality Criteria (AWQC) exceeded in ground water but due to lack of ecological impacts definitely attributable to ground water discharge, modification of AWQC may be appropriate before application as ground water ARARs; Treatment alternatives selected to treat ground water contaminants which exceed AWQC	Cap construction, sheet piling installation, ground water extraction/treatment/ discharge system and sediment containment would comply with criteria (i.e. wetland and coastal zone requirements); Mitigation of any impacted wetlands may be required	Would comply with action-specific ARARs applicable to monitoring, construction, stormwater discharge, landfill closure, hazardous waste characterization and air discharge/venting activities

TABLE ES-5
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 - No Action	Residual risk to human health and the environment remains; Provides no long-term protection; 5-year review required
Alternative 2 - Limited Action	May be effective in the long-term in reducing risks to humans but residual risk to the environment remains; Provides no long-term protection against environmental exposures to surface contaminants, sediments or leachate seeps; Monitoring would identify any changes in ground water, surface water or sediment quality; 5-year review required
Alternative 3 - Containment	Effective in the long-term in eliminating exposures to surficial contaminants and sediment as well as leachate seeps; Long-term monitoring would provide a means of monitoring any changes in ground water, sediment or surface water quality which could result in measurable impacts to ecological receptors; 5-year review required
Alternative 4 - Containment with Ground Water Treatment	Effective in the long-term in eliminating exposures to surficial contaminants and sediment as well as leachate seeps; Ground water extraction and treatment would minimize potential impacts due to migration of contaminated ground water; Long-term ground water monitoring would provide a means of monitoring any changes in ground water once treatment is discontinued; Permanence in eliminating future re-contamination of ground water is not ensured once treatment is discontinued; 5-year review required

TABLE ES-6
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
REDUCTION IN TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 – No Action	Provides no reduction in contaminant toxicity, mobility or volume through treatment
Alternativ 2 – Limited Action	Provides no reduction in contaminant toxicity, mobility or volume through treatment
Alternative 3 – Containment	Provides no reduction in contaminant toxicity, mobility or volume through treatment; Reduces contaminant mobility through containment features
Alternative 4 – Containment with Ground Water Treatment	Provides no reduction in soil/waste or sediment contaminant toxicity, mobility or volume through treatment Reduces ground water toxicity through treatment although re-contamination of ground water may occur following discontinuation of treatment

TABLE ES-7
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
SHORT-TERM EFFECTIVENESS
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 - No Action	Effective in short-term; However, remedial action objectives are not achieved
Alternative 2 - Limited Action	Effective in short-term; However, remedial action objectives are not achieved
Alternative 3 - Containment	Could result in increased short-term risks due to potential disruption of contaminated surficial materials and sediments; Remedial action objectives achieved
Alternative 4 - Containment with Ground Water Treatment	Could result in increased short-term risks due to potential disruption of contaminated surficial materials and sediments and operation of on-site treatment systems; Remedial action objectives achieved

TABLE ES-8
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
IMPLEMENTABILITY
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 - No Action	Requires no implementation other than a five-year review; Would not limit the implementation of other remedial actions
Alternative 2 - Limited Action	Long-term monitoring program easily implemented; Would not limit the implementation of other remedial actions; Would limit feasibility of utilizing the site for future recreational uses, in accordance with the Base Reuse Plan
Alternative 3 - Containment	Implementable within a one- to two-year period; materials and services readily available; Could complement future recreational or conservational site use; Presence of cap and sediment containment could impact implementation of other remedial actions, if required
Alternative 4 - Containment with Ground Water Treatment	Implementable but requires extended operational period; Materials and services readily available; Could complement future recreational or conservational site use; Presence of cap and sediment containment could impact implementation of other remedial actions, if required

TABLE ES-9
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
COST
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE, RI

ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT WORTH O&M COST (1)	TOTAL PRESENT WORTH (2)
Alt mative 1 – No Action	– –	– –	– –	Nominal (3)
Alternative 2 – Limited Action (4)	$61,000	$116,000	$1,800,000	$2,200,000
Alt mative 3 – Containment (5)				
Native Soil Cap	$2,400,000	$118,000	$1,800,000	$5,000,000
Single–Barrier Hybrid Cap	$2,700,000	$122,000	$1,900,000	$5,600,000
Alternative 4 – Containment with Ground (6) Water Treatment	$7,200,000	$240,000	$3,700,000	$13,000,000

Note: Costs are presented based on a combination of individual alternative costs as presented in Section 4 tables.
(1) – Based on 5% discount rate
(2) – Includes 20% contingency on all components
(3) – The only cost associated with the implementation of Alternative 1 would be that associated with conducting a five–year review of the no action decision.
(4) – For costing purposes, Alternative 2 consists of Alternatives S/W–2 and GW–2A
(5) – For costing purposes, Alternative 3 consists of Alternatives SD–3 and GW–2A combined with Alternatives S/W–3A or S/W–3B
(6) – For costing purposes, Alternative 4 consists of Alternatives S/W–3B, GW–2A, GW–3B, GW–4A, GW–4B, GW–4D and GW–4F

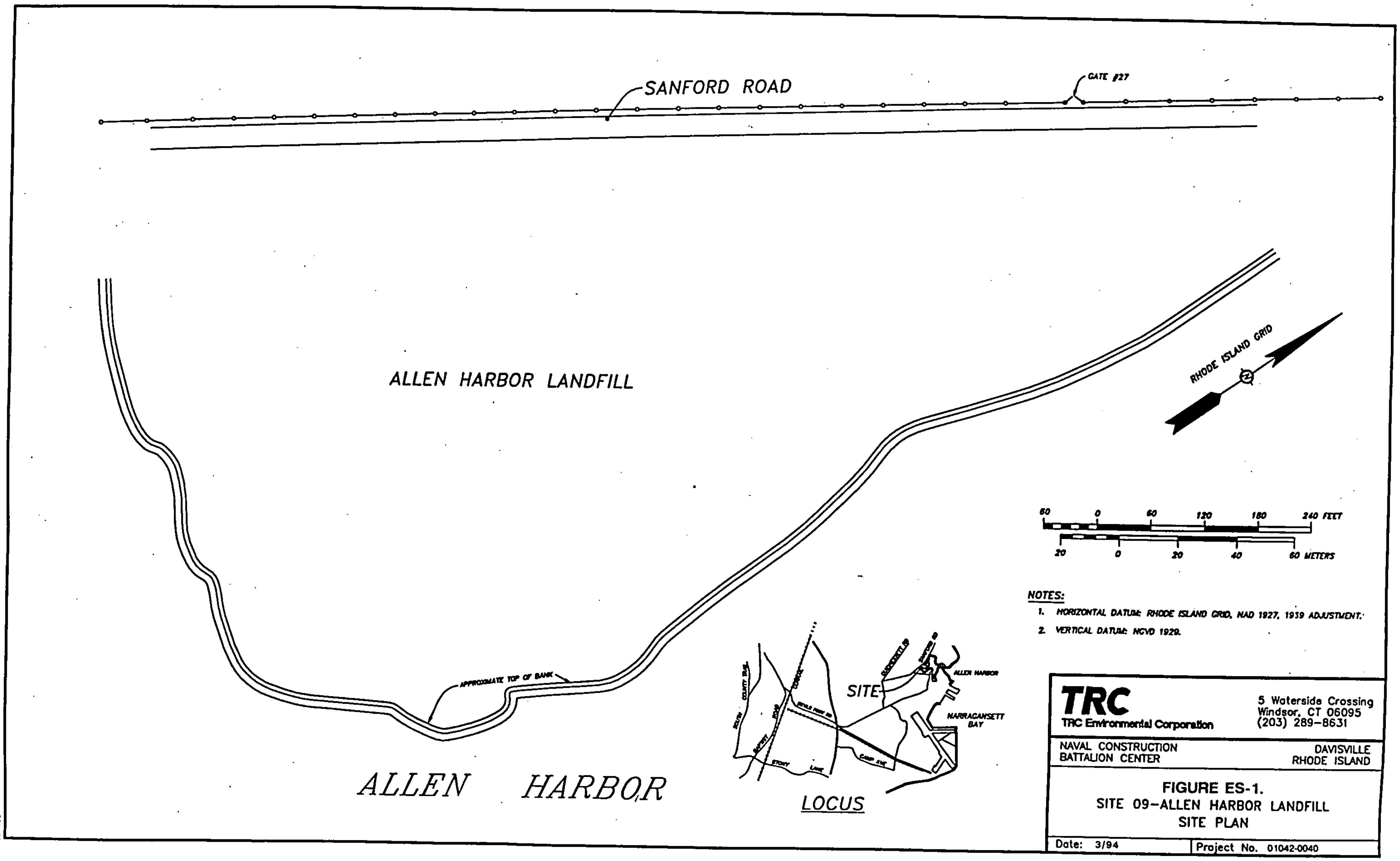

FIGURE ES-1.
SITE 09–ALLEN HARBOR LANDFILL
SITE PLAN

1.0 INTRODUCTION

TRC Environmental Corporation (TRC) is conducting a Remedial Investigation/Feasibility Study (RI/FS) at the Naval Construction Battalion Center, located in the northeast section of the town of North Kingstown, Rhode Island (NCBC Davisville). The RI/FS is being conducted under the Navy's Installation Restoration Program and in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). The study is being performed by TRC under Contract N62472-85-C-1026 for NORTHNAVFACENGCOM.

The Feasibility Study process was formulated by the U.S. Environmental Protection Agency (USEPA) to properly implement CERCLA. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP, 40 CFR Part 300) establishes the framework for performing Feasibility Studies. Further definition of the FS process is provided in the Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (USEPA, 1988a).

Previous investigations under which environmental data for the NCBC Davisville facility were developed include the following:

- Initial Assessment Study (IAS) (Hart, 1984a);
- Verification Step Report (part of a Confirmation Study) (TRC, 1987); and
- Phase I RI Draft Final Report (TRC, 1991).

Based on these studies, twelve sites were identified at NCBC Davisville for which Feasibility Study efforts were initiated. The site numbers were assigned during the IAS and have been retained under this investigation for consistency. The twelve sites were initially grouped for the purposes of conducting Feasibility Studies as follows:

- Group I Sites
    - Site 05 - Transformer Oil Disposal Area
    - Site 06 - Solvent Disposal Area
    - Site 13 - Disposal Area Northwest of Buildings W-3, W-4 and T-1
- Group II Sites
    - Site 08 - DPDO Film Processing Disposal Area

- Group III Sites
    - Site 12 - Building 316, DPDO Transformer Oil Spill Area
    - Site 14 - Building 38, Transformer Oil Leak Area
- Group IV Sites
    - Site 02 - CED, Battery Acid Disposal Area
    - Site 03 - CED, Solvent Disposal Area
- Group V Sites
    - Site 07 - Calf Pasture Point
    - Site 09 - Allen Harbor Landfill
- Group VI Sites
    - Site 10 - Camp Fogarty Disposal Area
- Group VII Sites
    - Site 11 - Fire Fighting Training Area

Figure 1-1 provides a summary of the approach being used in this investigation to formulate appropriate remedial responses for the NCBC Davisville sites. The FS is being conducted in phases. The first step of the Feasibility Study process, the Initial Screening of Alternatives or ISA, was conducted for the twelve sites on the basis of Phase I RI information. Two ISA reports were prepared (TRC, 1993a and 1993b), one which addressed the Group I, Group II, Group III and Group VI sites and the second which addressed the remaining groups of sites. The ISA reports incorporate the following steps:

- Introduction/Background Information
- Assessment of Applicable or Relevant and Appropriate Requirements (ARARs)
- For each group of sites:
    - Site-Specific Information
    - General Response Actions
    - Identification and Screening of Technologies
    - Development and Initial Screening of Alternatives
- References

Subsequent to the initiation of the Feasibility Study activities, the Group III Sites, Sites 12 and 14, were addressed separately through the development of a Risk Assessment Technical

Memo (TRC, 1993c), a Proposed Plan for additional remedial activities, and the development and signature of a Record of Decision (ROD).

Also subsequent to the development of the ISA Reports, the Phase II Remedial Investigation was conducted, with the results presented in a series of draft reports (TRC, 1993d, 1993e, 1993f). Included in the Phase II RI are a Human Health Risk Assessment, which considers both Phase I and Phase II RI data in the evaluation of potential risks to human health, and an Ecological Risk Assessment, which evaluates the potential risks to the environment posed by the investigated sites.

This document, the Detailed Analysis of Alternatives (DAA), assesses the need for the application of potential remedial technologies at Site - 09 Allen Harbor Landfill, as defined by existing site information. It builds upon the evaluation conducted in the ISA (TRC, 1993b) and incorporates the results of the Phase II RI in the evaluation of potential remedial technologies for Site 09. The format followed within this DAA generally follows the original ISA format, with facility background information followed by a site-specific evaluation of the nature and extent of contamination, and the potential risks to human health and the environment posed by the site. The report presents the refinement of remedial response objectives, originally proposed within the ISA, the refinement of remedial alternatives, and detailed individual and comparative analyses of the remedial alternatives.

1.1 Facility Location and Description

NCBC Davisville is located in the northeast section of the town of North Kingstown, Rhode Island, approximately 18 miles south of Providence. A site location map is provided in Figure 1-2. NCBC-Davisville is composed of three areas including the Main Center, the West Davisville storage area, and Camp Fogarty, a training facility located approximately 4 miles west of NCBC-Davisville. A significant portion of NCBC Davisville is contiguous with Narragansett Bay. These areas are noted in Figure 1-3.

Adjoining NCBC-Davisville's boundary on the south is the decommissioned Naval Air Station (NAS) Quonset Point that was declared excess to the Navy in April, 1973. The Quonset Point area is currently owned by the Rhode Island Port Authority (RIPA) and the Rhode Island

Department of Transportation (RIDOT), along with some private companies. Hereafter, this area will be referred to as NAS Quonset Point, to distinguish it from NCBC Davisville.

1.2 NCBC Davisville History

Quonset Point was the location of the first annual encampment of the Brigade Rhode Island Militia in 1893. During World War I, it was designated for the mobilization and training of troops and later was the home of the Rhode Island National Guard. In the 1920s and 1930s, Quonset Point functioned as a summer resort.

In 1939, Quonset Point was acquired by the Navy to establish a Naval Air Station (NAS), and construction began in 1940. During construction, millions of cubic yards of sediment were dredged to create a ship basin and channel.

By 1942, the operations at NAS Quonset Point had expanded into what is now called NCBC Davisville. Land at Davisville adjacent to NAS Quonset Point was designated the Advanced Base Depot, and the first of two piers was constructed. Later that year the Naval Construction Training Center (NCTC), known as Camp Endicott, was established to train the newly established construction battalions.

After World War II, activities at NAS Quonset Point remained the same, providing an operating base for aircraft and ships. After 1947, NAS Quonset Point was a site of carrier-based jet aviation. The Antarctic Development Squadron Six was moved to NAS Quonset Point in 1956. A Naval Air Rework Facility (NARF) was created there in 1967. The Naval Hospital was established in 1968.

The NCBC Davisville area was inactive between World War II and the Korean Conflict. In 1951 it became the Headquarters Construction Battalion Center (CBC). In 1974, the NAS and NARF at Quonset Point were decommissioned, and operations at Davisville were greatly reduced. In 1980, RIPA purchased NAS Quonset Point and the two Davisville piers from the Navy. In 1989, the closure of Davisville was announced, and all operations at Davisville were phased down to the present staffing levels for Public Works, Maintenance, Security and Navy Personnel. The facility will be officially closed on April 1, 1994, and subsequently held under caretaker status by the Naval Facilities Engineering Field Division (Northern Division). Under caretaker status, a civilian presence will be maintained at or near NCBC Davisville to monitor and provide oversight for all identified hazardous waste sites.

A Base Reuse Committee was established to develop a Comprehensive Reuse Plan to guide future use and development of the NCBC Davisville facility following closure. The proposed land uses defined under the Reuse Plan have been used as the basis for evaluation of future site uses in the RI/FS evaluations.

1.3 History of Facility Response Actions at NCBC Davisville

1.3.1 Previous Investigations - U.S. Navy

In 1983, Fred C. Hart Associates, Inc. (Hart) conducted an Initial Assessment Study (IAS) under contract to the Navy Assessment and Control of Installation Pollutants (NACIP) Office, with the purpose of identifying areas where potential contamination from past waste storage, handling or disposal practices at NCBC Davisville could pose threats to human health and the environment. The IAS identified a total of 14 potentially contaminated sites at NCBC Davisville (Hart, 1984a) Based on regulatory review of the IAS report, seven additional areas were added for a total of 21 potential areas of contamination at NCBC Davisville.

A Confirmation Study (CS) - Verification Step was initiated by TRC Environmental Consultants, Inc. (TRC) in March 1985. The purpose of the CS was to assess the nature and extent of contamination at 13 of the 21 sites identified in the IAS. The sites investigated during the Verification Step program included:

- Site 02 - CED Battery Acid Disposal Area;
- Site 03 - CED Solvent Disposal Area;
- Site 04 - CED Asphalt Disposal Area;
- Site 05 - Transformer Oil Disposal Area;
- Site 06 - Solvent Disposal Area;
- Site 07 - Calf Pasture Point;
- Site 08 - DPDO Film Processing Disposal Area;
- Site 09 - Allen Harbor Landfill;
- Site 10 - Camp Fogarty Disposal Area;
- Site 11 - Fire Fighting Training Area;
- Site 12 - DPDO Transformer Oil Spill Area;
- Site 13 - Disposal Area Northwest of Buildings W-3, W-4 and T-1; and
- Site 14 - Building 38, Transformer Oil Leaks.

1.3.2 Previous Investigations - USEPA

NCBC Davisville was proposed by the USEPA for inclusion on the National Priority List (NPL) in July 1989. NCBC Davisville was added to the NPL on November 21, 1989. USEPA developed a Hazard Ranking System (HRS) scoring package to support the proposed and final listings (USEPA, 1989a). The HRS package was based on existing information; a Preliminary Assessment/Site Investigation was not performed.

The HRS package noted that of the 24 potential sites which were identified in a combined study of NCBC Davisville, West Davisville, Camp Fogarty, and the decommissioned Quonset Point, the most serious sites of concern, and the sites which were aggregated to form the basis of the ranking package, are Site 09 - Allen Harbor Landfill and Site 07 - Calf Pasture Point.

Of the 24 potential sites listed in the HRS package, the areas designated 1 through 14 coincide with the 14 areas identified in the Navy's IAS. The remaining potential areas, 15 through 24, were identified by the EPA from an "Off-Site Activity Investigation" report (Hart, 1984b). The HRS package notes that areas 15 through 24 are on property not currently owned or operated by the U.S. Navy and are not included as part of the NPL site. Several of these areas are being investigated by the Army Corps of Engineers' program aimed at former defense facilities.

1.3.3 Current Remedial Investigation

In 1988, the Navy's three-phase NACIP Program was restructured to conform with USEPA's four-phase program. This change was predicated by the Superfund Amendments and Reauthorization Act (SARA) of 1986. The U.S. Navy changed its NACIP Program to closely parallel the USEPA requirements for remedial actions at Superfund sites. The Navy's program is now called the Installation Restoration (IR) Program. Under the IR Program, current investigations at NCBC-Davisville are in the Remedial Investigation/Feasibility Study (RI/FS) phase.

In March 1988, TRC was tasked by the Navy to implement recommendations of the Confirmation Study - Verification Step by developing a Plan of Action as a NACIP Confirmation Study - Characterization Step to conduct more extensive sampling. Shortly after initiating this task, the Navy requested TRC to develop a Remedial Investigation (RI) Work Plan conforming to the newly-established Navy IR Program, and to the extent possible, conforming to current EPA requirements under the NCP and the USEPA draft RI guidance (USEPA, 1988a). The resulting Phase I RI/FS Work Plan included a Field Sampling Plan, a Health and Safety Plan, a Quality Assurance Project Plan and a Data Management Plan (TRC, 1988). The Phase I RI field investigations were conducted from September 1989 to March 1990 and the Phase I RI Draft Final Report was submitted to the Navy in May 1991.

A Phase II RI/FS Work Plan was developed by TRC in 1992 and was implemented in the field over a period spanning from December 1992 through September 1993. The results of the Phase I and Phase II RIs are presented in a series of technical reports for the various sites (TRC, 1993d, 1993e, 1993f).

1.4 Regional Geology, Hydrogeology and Hydrology

The regional and site-specific geology, hydrogeology and hydrology are briefly discussed in the following sections. More comprehensive descriptions are provided in the Remedial Investigation Technical Report (TRC, 1993d).

1.4.1 Regional Geology

The area of Narragansett Bay, including the surrounding lowlands and islands in the Bay, overlies the Narragansett Basin. This geologic structure is a complex syncline of Pennsylvanian Age metasedimentary rocks about 12 miles wide and up to 12,000 feet deep. The Narragansett Basin's western limit is about 3 miles west of NCBC Davisville, and its eastern edge is close to Fall River, Massachusetts. All of the NCBC-Davisville sites, except Site 10 - Camp Fogarty, overlie the Narragansett Basin. The bedrock is overlain by various glacial deposits up to 200 feet thick that have left the basin area relatively flat compared to the surrounding areas (Schafer, 1961).

The bedrock forming the basin is comprised of five formations which consist chiefly of non-marine conglomerates, sandstones, and shales. The principal unit is the Rhode Island Formation, which consists of a gray-greenish fine to coarse conglomerate, sandstone, lithic graywacke, graywacke, arkose, shale, and a minor amount of meta-anthracite and anthracite.

According to Johnson and Marks (1959), in the vicinity of NCBC Davisville, the bedrock is more than 90 feet below sea level in the West Passage of Narragansett Bay, greater than 70 feet below sea level just west of Frys Pond, nearly 50 feet below sea level near the West Davisville facility, and nearly 100 feet above sea level near Camp Fogarty. The Geologic Map and Sections of the Wickford Quadrangle, Rhode Island (Williams, Bulletin 1158-C, 1964) and visual observations identify a major bedrock outcrop just west of Frys Pond (approximately 300 yards east of Site 05).

The unconsolidated soils overlying the bedrock consist of three general types of glacial deposits: till, water-laid deposits, and wind-deposited material. In the Davisville area, till is exposed along highlands such as Lippitt Hill, the hillside due west of the rifle and pistol range at Camp Fogarty, and along the hillside of the ridge between West Davisville and NCBC Davisville. Just northeast of Site 02, there is an end moraine deposit which controlled the pro-glacial melt water drainage system.

Most of the surficial geologic soils in the Davisville area are water-laid deposits. Melt water streams flowing along the west side of the end moraine near Site 02 deposited a sequence of sands and silts over most of NCBC Davisville, including Sites 02, 03, 05, 06, 11, 13, and 14. Melt water streams also deposited layers of sand and silt near West Davisville (Sites 08 and 12) and the Allen Harbor Landfill (Site 09). Fine-grained glaciolacustrine soils underlie Calf Pasture Point (Site 07). At Camp Fogarty (Site 10), the rifle and pistol range overlies a kame terrace consisting of sand and gravel deposited by melt water streams which flowed alongside the glacier which moved through the Hunt River valley.

Wind deposited materials in the Davisville area are loose, heterogeneous, and relatively thin in comparison to the other glacial deposits in the area [10 feet at the higher elevations, and over 150 feet thick in some portions of the bedrock valleys (Schafer, 1961)].

1.4.2 Regional Hydrogeology

Ground water hydrogeology in the Davisville area is controlled by the geographic and geologic setting. The underlying bedrock units have primary porosities (pore openings between the grains of mineral crystals forming the rock) of less than 1 percent and very low secondary porosities (joints, fractures and openings along bedding planes). The only openings capable of yielding significant amounts of ground water are the secondary openings. In general, well yields from the bedrock formations are generally low, about 22 gallons per minute (gpm) from an average depth of approximately 225 feet. Flow from the secondary openings is greatest in the top 250 to 300 feet of bedrock (Rhode Island Development Council, 1952). In the Davisville area, the bedrock is not the principal aquifer and, therefore, is penetrated by only a small portion of wells.

The glacial soils in the Davisville area generally consist of stratified sand/gravel interbedded with very fine sand and silt; glacial till (a heterogeneous mixture of silt, sand, clay, and gravel), and stratified sand or gravel interbedded with varying amounts of glacial till. All of these materials will yield ground water, but only the stratified sands or gravels are permeable enough to yield large quantities of water for development. These very permeable materials form the Hunt Ground Water Reservoir or Hunt River Aquifer (previously known as the Potowomut-Wickford Aquifer), which is the principal source of potable water in the area. The specific yield capacities can range between 5 and 300 gallons per minute per foot drawdown (gpm/ft), with some wells yielding as much as 2,700 gpm. A hydrologic review of the aquifer recharge and discharge shows the long-term sustained safe yield of the entire Hunt Ground Water Reservoir is about 8 million gallons per day (mgd) (GZA, 1992).

Ground water in the Davisville area is unconfined; therefore, movement of the ground water is in direct response to gravity. The direction of regional ground water flow in the Davisville area is west to east, from the highlands towards Narragansett Bay. For small localized areas, the direction of ground water flow will be to the nearest downhill discharge area.

Ground water quality beneath the Davisville area is classified by the RIDEM as GAA-NA (Sites 08, 10, and 12) and GB (Sites 02, 03, 05, 06, 07, 09, 11, 13 and 14). GAA ground water is considered to be suitable for public drinking water use without treatment. Non-attainment areas (NA) are those areas that have pollutant concentrations greater than ground water quality standards for the applicable classification; a goal of restoration to ground water quality consistent with the standards is applicable to such areas. GB ground water is not suitable for public or private drinking water use. Areas were classified as GB because of known or presumed ground water degradation due to urbanization and/or identified waste disposal sites.

Rhode Island regulations do not require cleanup to drinking water standards, but if RIDEM determines resultant impacts need to be addressed or if contaminant levels pose a risk or contaminants migrate off-site, the Department can require remediation. The need for cleanups are determined on a site-by-site basis.

The ground water quality of the Hunt Ground Water Reservoir is suitable for most purposes. It generally contains less than 70 ppm of dissolved solids and the pH is slightly acidic to neutral, with a range of 5.5 to 7.0. The principal anions in the ground water are bicarbonate, sulfate, chloride and nitrate, all usually present at concentrations less than 25 ppm. In the vicinity of Narragansett Bay, the chloride concentration may exceed 250 ppm, due to salt water intrusion. The principal cations in the ground water are calcium, sodium, magnesium and potassium, each generally present at concentrations less than 10 ppm, resulting in soft water. Iron and manganese usually do not exceed drinking water standards (Rosenshein, Gonthiel and Allen, 1968).

1.4.3 Area Water Use

Available information (Personal Communication, Cohen, Smith, 1992) indicates that potable water in the Davisville area is supplied by either the North Kingstown Water Department or the Rhode Island Port Authority.

The North Kingstown Water Department supplies the non-military portion of Davisville and North Kingstown with water. North Kingstown operates three wells located in the Hunt Ground Water Reservoir and has proposed an additional well location (GZA, 1992). The locations of these wells are indicated in Figure 1-4.

The Rhode Island Port Authority (RIPA) supplies water on a wholesale basis to the Navy and some private users on Quonset Point (Personal Communication, Cohen, 1992). RIPA obtains its water from a series of three ground water supply wells located in the Hunt Ground Water Reservoir, as indicated in Figure 1-4. The Kent County Water Authority, which supplies water to towns north of North Kingstown, also maintains a ground water production well in the Hunt Ground Water Reservoir, also shown in Figure 1-4.

No active ground water supply wells exist at NCBC-Davisville on Navy property (Personal Communication, Cohen, 1992).

A search of potential private well locations was conducted within a one-mile radius of Site 9 as part of the Phase II RI. The entire search area is located within the Town of North Kingstown. Following an identification of street names within the study area, specific street addresses were identified based upon a review of town tax records, and addresses at which water service is provided were identified based upon a review of town water department records. To identify potential addresses where private wells could be in use, the town tax addresses were compared with the water service addresses. From this comparison, an initial list of potential private well users was compiled. Tax codes noted for each address on the town tax list indicate the use of the property. These codes were used to eliminate all vacant lots from further consideration, thereby reducing the list of potential addresses where private wells could be in use. All tax codes that described property uses that could potentially utilize a potable water source were retained. A total of thirty addresses located on seven streets were identified as potentially using private wells in this evaluation. The street locations are highlighted in Figure 1-5. As shown, three of the streets, Mountview Avenue, Pettee Avenue and Coolidge Avenue are located to the north of Site 09. Fletcher Road and Signal Rock Road are located west of the site. Boyer Street and Tidal Drive are located southeast of the site, adjacent to the eastern side of Allen Harbor.

1.4.4 Regional Hydrology

All of the investigated sites lie within the Hunt River drainage basin. The basin is about 60 square miles in area and is divided into four smaller sub-basins (Figure 1-6). Camp Fogarty and West Davisville lie within the Potowomut River basin, and the Main Center of NCBC Davisville lies within the Coastal River basin. All stream flow and river flow eventually discharges into Narragansett Bay (Figure 1-6). Surface water features in the immediate vicinity of NCBC Davisville are indicated in Figure 1-7. During most of the year, a part of the stream flow consists of water discharged from detention storage in natural, as well as man-made impoundments. The remaining flow is from direct runoff of precipitation and from base runoff consisting largely of ground water discharge. The ground water contributes close to 50 percent of the average annual stream flow:

Annual precipitation in the area has ranged from 24.8 to 66.2 inches with an average of 42.3 inches. The frequency of measurable precipitation events (0.01 inch or greater) averages once every 3 days and is evenly distributed throughout the year. The average snowfall is almost 40 inches and has varied from 11.3 to 75.6 inches. Roughly 36 percent of the precipitation actually recharges the ground water system; the other 64 percent runs off into streams or is lost through evapotranspiration (GZA, 1992).

The surface water and ground water quality are similar since ground water contributes a major portion to stream flow. The principal anions are bicarbonate, sulfate, chloride, and nitrate. The principal cations are calcium, sodium, magnesium, and potassium. The pH ranges between 5.5 and 7.0. The iron concentrations in stream water vary from 0.03 to 3.7 ppm with the higher concentrations detected in Sandhill Brook, the lower reach of Hunt River, and the Potowomut River. Manganese concentrations range between less than 0.01 and 0.54 ppm (Rosenshein, Gonthiel, and Allen, 1968).

2.0 SITE CHARACTERIZATION

A summary of the characterization of Site 09, the focus of this report, is presented in this section.

2.1 Site Location and Description

Site 09 - Allen Harbor Landfill covers an area of approximately 13.5 acres on the western side of Allen Harbor. A general site location map is provided in Figure 2-1. The landfill is bounded to the east and south by Allen Harbor, and to the west by Sanford Road. A marsh is located to the west of the landfill, on the opposite side of Sanford Road. A fence runs along the west side of Sanford Road, at the edge of Navy property. Access to the landfill is controlled by a fence and a locked gate at the Sanford Road entrance (see Figure 2-1).

Allen Harbor is currently overgrown with a mixture of shrubs, small trees, and grasses. The only extensive areas of stressed vegetation appear to be the locations of former pavement and/or access roads. Substantial amounts of building demolition debris and rusted metallic objects are visible at various locations across the landfill surface. The landfill rises approximately 15 to 20 feet above the high tide mark along its southeastern perimeter. Large pieces of demolition debris, including significant amounts of structural steel, are visible along the nearly vertical face of the landfill toe. Although the landfill's surface is generally flat, there are several localized swales and berms which appear to consist of cover material which was not completely graded. This cover material is discontinuous over the landfill and, where present, is reported to vary from one to three feet in thickness.

The Comprehensive Reuse Plan for NCBC Davisville specifies the future use of Site 09 as a recreation and conservation area.

2.2 Site History Overview

From 1946 to 1972, an area of land protruding into the western portion of Allen Harbor was used as a landfill for wastes generated at NCBC Davisville and the former NAS Quonset Point. A variety of wastes, including preservatives, paint thinners, degreasers, PCBs, asbestos, ash, sewage sludge, and contaminated fuel oil were reportedly disposed of in the landfill, usually by burning and then covering. Table 2-1 provides a summary of waste material disposed of at

Allen Harbor Landfill, with the approximate periods of disposal and estimated disposal volumes noted (Hart, 1984a).

2.3 Site Geology, Hydrogeology and Hydrology

2.3.1 Site Geology

The drilling of four soil borings and digging of nine test pits during the Phase I RI and the drilling of eight test borings and fifteen monitoring well borings during the Phase II RI were used to characterize the subsurface soils and waste at the Allen Harbor Landfill.

The Interim Soil Survey Report for North Kingstown, Rhode Island (USDA, 1973) maps the majority of Site 09 surface soils as landfill materials. Soils along the northwestern edge of the site along Sanford Road are mapped as Windsor loamy sand, zero to three percent slopes, soils along the western edge of the site along Sanford Road are mapped as Pawcatuck peat (tidal marsh) and soils in the northernmost portion of the site are mapped as lying at the boundary between the Windsor and Pawcatuck surface soil units.

While 1939 and 1951 aerial photographs of the Site 09 area confirm that landfilling was underway prior to 1951, the USGS surficial geologic map of the Wickford, Rhode Island quadrangle (Schafer, 1961) does not identify the Site 09 area as consisting of artificial fill. The central portion of the Site 09 landfill area is mapped as surficial overburden deposits of Pleistocene glacial water-laid, ice-contact sediments, consisting of sand, gravel and silt. The shoreline of the landfill area, as well as the wetland areas to the west of the landfill area, are mapped as recent swamp and marsh deposits, consisting of muck, peat, silt and sand.

As mentioned previously in Section 2.1, a cover material is present on the site, although it is discontinuous. This cover material consists of a poorly sorted sand and gravel with silt and/or clay-sized particles. Where present, its thickness varies from one to three feet.

A broad range of geologic materials were encountered on site during the remedial investigations. In general, these materials may be grouped (from the top down) as urban fill, sand and silt, and silt. Each unit is described below.

Each of the soil and monitoring well borings located east of Sanford Road encountered the urban fill material. Where encountered, the fill ranged in thickness from 4 feet to 29 feet. The average fill thickness in the Phase II borings was approximately 15 feet. The fill material consisted of a heterogeneous mixture of soil and municipal and construction waste materials. The material ranged from a medium dense to very dense mixture which included glass, plastic metal, asphalt, wood and construction debris. As much as five to six feet of fill are present below the water table in the southeastern portion of the site and as much as 13 feet of fill is below the water table in the south-central portion of the site.

The native sand and silt unit encountered directly under the fill unit is heterogeneous and is comprised of lenses of fine to medium to fine to coarse sand interbedded with sandy silt and organic silts and peat. The sand and silt unit was encountered in nearly all of the borings completed and ranged in thickness from less than one foot in the southeastern portion of the site to approximately 20 feet in the central portion of the site.

The silt unit extends from the base of the native sand and silt unit to the top of bedrock. Where completely penetrated by borings, the unit ranges in thickness from approximately 27 feet to 54 feet. The unit consists of soft to very stiff grey silt, with trace quantities of fine sand.

Bedrock was encountered at elevations ranging from -57.8 feet msl in the northeastern portion of the site to -35.2 feet msl in the central portion of the site. The bedrock surface appears to form a high in the west-central portion of the landfill and slopes down away from the high in all directions, most sharply to the northeast and northwest. Seismic refraction surveys completed at the site indicate that the competent bedrock at Site 09 is located from approximately 25 to 81 feet below ground surface (elevations range from -69.2 feet msl to -15.4 feet msl), and appears to dip to the northwest.

According to the USGS bedrock geologic map of the Wickford, Rhode Island quadrangle (Williams, 1964), Site 09 is underlain by bedrock belonging to the Pennsylvanian Rhode Island Formation. Nx rock cores were collected of competent bedrock at three deep monitoring well locations. At 09-MW6D and 09-MW12D, the cores were generally characterized by the presence of fine- to medium-grained meta-sandstone gneiss with vein-healed natural fractures and some iron oxide-stained fractures. The core from 09-MW13D consisted of interbedded brittle shattered dark grey shale and massive, competent light grey gneiss.

2.3.2 Site Hydrogeology

Contour maps of the shallow and deep ground water elevations measured in Site 09 monitoring wells on August 13, 1993 and September 17, 1993 are presented as Figures 2-2 through 2-5. The deep and, to a lesser extent, the shallow ground water horizontal hydraulic gradients and flow directions are a function of the time position within a given tidal cycle.

The shallow ground water flow patterns at Site 09 are complex due to the presence of fill materials and the landfill's proximity on three sides to Allen Harbor or wetlands. The highest ground water elevations are in the northern portion of the site, with a roughly north-south trending zone of higher shallow ground water elevation trending through the central portion of the landfill. From this area of higher elevation, the shallow ground water generally tends to flow radially out towards Allen Harbor or towards the marshy areas which lie to the southwest of the site. In the southwestern portion of the site, well 09-MW5S was installed in a fill mound surrounding by low-lying topography, and a local area of high shallow ground water was identified in this portion of the site. While most of this ground water presumably flows southward toward Allen Harbor, some portion of this ground water may flow northwestward. The presence of the water table in fill materials is generally limited to the portion of the site south of well location 09-MW7.

The deep ground water elevation contour maps (Figures 2-3 and 2-5) reflect how tidal effects have a greater impact on the Site 09 deep ground water than on the shallow ground water. A reversal in flow direction is apparent when comparing the August 19, 1993 monitoring event, conducted during a lower tidal stage, to the September 17, 1993 monitoring event, conducted during a higher tidal stage.

Vertical hydraulic gradients were calculated for seven sets of paired monitoring wells at the site, as presented in Table 2-2. A positive hydraulic gradient indicates an upward flow and a negative gradient indicates a downward flow. For the two monitoring events, vertical gradients ranged from -4.89 x 10^{-2} ft/ft to 5.16 x 10^{-2} ft/ft. Positive vertical gradients were measured at 09-MW2S/3D, 09-MW8S/D, 09-MW10S/D AND 09-MW13S/D during both events while 09-MW6S/D, 09-MW7S/D and 09-MW9S/D exhibited negative gradients during the first event and positive gradients during the second event. It should be noted that 09-MW6D, 09-

MW7D and 09-MW9D exhibited the highest deep ground water contaminant levels, as described in Section 2.6. The variability in the measurements may be due at least in part to tidal effects.

Horizontal hydraulic gradients were also calculated from the water level measurements. Representative average horizontal gradients for both the shallow and deep ground water are presented in Table 2-3. Average horizontal gradients for shallow ground water ranged from 4.20×10^{-3} ft/ft to 1.69×10^{-2} ft/ft. Average deep ground water horizontal gradients ranged from 5.91×10^{-4} ft/ft to 4.74×10^{-3} ft/ft.

The calculated average horizontal hydraulic gradients, along with the hydraulic conductivity and effective porosity values, were used to calculate average linear velocity values at the site. The average linear velocities, calculated on the basis of shallow and deep hydraulic conductivities of 11.5 and 1.0 ft/d (derived from Phase II RI slug tests), respectively, and an assumed effective porosity of 20% for the silty sands, are presented in Table 2-3. Average linear velocities of the shallow ground water ranged from 0.24 ft/d to 0.97 ft/d. Average deep linear velocities ranged from 0.004 ft/d to 0.03 ft/d.

In order to evaluate ocean tidal effects on the ground water, continuous ground water levels were recorded at several piezometer clusters and wells during three monitoring events. The water level data indicated that the piezometers or well clusters installed closest to Allen Harbor showed a greater response to tidal fluctuations than the clusters located further inland. Greater responses were also measured in piezometers or wells screened below the water table, as compared to those screened at the water table. The data also exhibited a dissipation in magnitude of tidal response and a greater time lag with increasing distance inland.

2.3.3 Site Hydrology

Allen Harbor Landfill is situated with Allen Harbor to the east and wetland areas to the north, west and south. The landfill has been built up and is the highest topographic feature adjacent to Allen Harbor. The irregular surface topography across the site determines runoff direction. Generally, the topography channels the runoff from the site toward two adjacent wetland areas (west of Sanford Road, between wells 09-MW1 and 09-MW2, and to the south of the site, near boring 09-B03). Shallow ground water seeps were identified as discharging from the landfill face during the Phase I RI, but no seeps were identified during the Phase II RI.

The effect of tides associated with the proximity of Allen Harbor is most readily seen in the wetland areas located to the north and south ends of the landfill. The tide flows in and out of these salt water marshes through culverts under Sanford Road. Typical tidal fluctuations between high and low tides are on the order of 3 to 4 feet.

Wetlands associated with the Allen Harbor tributary system were identified adjacent to Allen Harbor Landfill in the Ecological Assessment portion of the Phase II RI. A wetland drainage system (referred to as the Wetland G/F drainage system) is tributary to the southern and southwestern portions of Allen Harbor. It consists of a reed meadow/scrub-shrub swamp (Wetland G) and a salt marsh (Wetland F). Wetland G is bordered by Westcott Road to the north and east and by upland wooded and deteriorating developed areas to the south and west. Wetland F borders the southern shore of Allen Harbor as well as the southern edge of the landfill area, which is along the western side of Allen Harbor. Wetland G discharges to Wetland F to the north via a one-meter-wide stream channel that flows under a bridge on Westcott road. This drainage discharges to Allen Harbor via several diffuse braided channels and hollows, as well as a sinuous central stream channel flowing through the Wetland F salt marsh. Wetland F also receives drainage from off-site wetlands to the west via a culverted stream channel under Sanford Road. This drainage discharges to Allen Harbor via a narrow estuary.

2.4 Ecological Setting

As mentioned previously in Section 1.4, RIDEM has classified ground water in the vicinity of Site 09 as Class GB. Ground water classified GB encompasses those resources designated as not suitable for public or private drinking water use without treatment due to known or presumed degradation. GB classified ground water is primarily located at highly urbanized areas or in the vicinity of disposal sites for solid waste, hazardous wastes or sewage sludge.

The surface water quality of Allen Harbor is classified by RIDEM as Class SA sea water. Class SA sea water supports boating and contact recreational activities, shellfish harvesting for direct human consumption and fish and wildlife habitat. However, Allen Harbor has been closed to shellfishing.

Site 09 is located within the Allen Harbor Watershed. The Allen Harbor Watershed also includes salt marshes adjacent to Site 09 (reference Section 2.3.3), upgradient salt and freshwater marshes and the open water areas immediately north of the landfill. Allen Harbor is an estuarine embayment of the larger Narragansett Bay marine system and is connected to Narragansett Bay by a narrow, dredged channel.

Based on observations made during the ecological assessment activities for Site 09, the Allen Harbor Landfill is covered with relatively sparse vegetative growth that appears to be less than ten years old, including such species as sumac, willow, *Phragmites*, red cedar, grasses, flowering cherry and autumn olive. Twenty-two bird species were observed on the landfill, while the adjacent salt marsh exhibited several shore birds. The debris at the face of the landfill provides a hard intertidal substrate which supports *Ascophylum, Fucus, Littorina,* and *Balanus*. The salt marsh benthos is typical of New England salt marshes, and provides a feeding area for piscivorous birds, crab-eating birds, and small mammals.

The State of Rhode Island (RIDEM, 1989) conducted an endangered species survey of East Davisville, also referred to as the Main Center. It describes the area as having fringing saline and brackish marsh which do not provide suitable habitat for rare species, and upland areas which are slowly reverting to natural communities of shrubs.

2.5 Site Investigation Overview

2.5.1 Confirmation Study

Field investigations conducted during the Confirmation Study in 1985 included a radiation survey, surface soil sampling, surface water sampling, harbor sediment sampling, and clam sampling over two field mobilizations.

2.5.2 Phase I RI

The Phase I RI included the following field activities: the excavation and sampling of nine on-site test pits, the installation and sampling of four monitoring wells, and the sampling of four seepage areas along the shoreline at the toe of the landfill. Sampling locations are indicated in Figure 2-6. Samples were analyzed for the full Target Compound List

(TCL)/Target Analyte List (TAL). Cyanide, asbestos and TCLP analyses were also conducted on a limited number of samples.

2.5.3 Phase II RI

The scope of the Phase II RI was developed to further delineate the horizontal and vertical extent of contamination associated with the landfill and to provide a basis for the evaluation of contaminant fate and transport mechanisms, human health risks, ecological risks and remedial alternatives. Phase II field activities, conducted between December 1992 and August 1993, consisted of the following: a geophysical investigation which included a seismic refraction survey, an electromagnetic conductivity survey, and a magnetometer survey; sampling of surface soil at seven on-site surface soil sample locations and sixteen test/monitoring well boring locations; drilling and sampling of sixteen test/monitoring well borings; installation of six shallow and deep well clusters, as well as two shallow wells and one deep well; sampling of the fifteen new monitoring wells and four existing (Phase I) monitoring wells; installation of four piezometric well clusters along the toe of the landfill; and performance of single well hydraulic conductivity tests (slug tests). Phase II RI sampling locations are indicated in Figure 2-7. The surface and subsurface soil and ground water samples were analyzed for TCL and TAL parameters. Six of the seven surface soil samples were also analyzed for dioxins/furans. Three subsurface soil samples were analyzed for the Toxicity Characteristic Leachate Procedure (TCLP) parameters. Two undisturbed Shelby tube samples were collected from the gray silt material just below the fill at two well locations and ten-foot Nx cores of bedrock were collected at three deep monitoring well locations.

Surface water and sediment samples were collected at nine downstream reference stations (Stations 02 through 10) and one upstream reference station (Station 01) within the Allen Harbor Watershed in the general vicinity of Sites 07 and 09. Sampling station locations are provided in Figure 2-8. Of the ten sample stations, only two (Stations 09 and 10) were directly associated with Allen Harbor Landfill. These sample stations were intended to be located at leachate seep locations; however, since no seeps were identified in the field, the sampling locations were sited at the toe of the landfill face. The remainder of the sampling stations were used to establish background sediment and surface water quality entering Allen Harbor. Both sediment and surface water samples were analyzed for TCL and TAL parameters.

Also included within the scope of the Phase II RI was an investigation of background soil quality at the NCBC Davisville facility. Background soil quality results for inorganics are summarized in Table 2-4 and are considered in the evaluation of contaminant levels presented below.

2.5.4 Risk Assessment Pilot Study

A marine and estuarine ecological study of Allen Harbor, referred to as the Risk Assessment Pilot Study (RAPS) has been conducted under a separate program. The scope and results of this study is described in more detail in Section 2.7. While this program is separate from the RI/FS, it warrants consideration in the overall site evaluation process.

2.6 Nature and Extent of Contamination

The nature and extent of contamination based on the RI investigations is presented by chemical class below. Where appropriate, Confirmation Study results are also referenced. The scope of the Risk Assessment Pilot Study and a discussion of its conclusions in terms of potential impacts to Allen Harbor are presented separately in Section 2.7.

2.6.1 Volatile Organic Compounds (VOCs)

Surface Soils

During the Confirmation Study, a composite surface soil sample, collected from locations along the landfill's edge, just above the high tide water level, was submitted for Priority Pollutant analysis. No volatile organics were detected in the sample.

The Phase I RI analysis of volatile organics in surface soils identified the presence of chloroform and acetone, with the highest total VOC concentration, 46 ppb, detected in sample 09-B02-01.

During the Phase II RI, VOCs detected in the surface soil samples included acetone, 1,1,1-trichloroethane, tetrachloroethane and toluene. Acetone was detected at the highest concentrations, ranging from 11 ppb to 45 ppb. The remaining contaminants were detected at lower individual levels, ranging from 1 ppb to 12 ppb. Only two surface soil samples, 09-B02-01 and 09-MW5-01) exhibited multiple VOCs in a single sample (acetone and tetrachloroethene in 09-B02-01 and acetone, tetrachloroethene and toluene in 09-MW5-01).

Subsurface Soils

During the Phase I RI, VOCs detected in the subsurface soil samples included aromatic compounds and chlorinated hydrocarbons. The highest levels of VOCs were detected at test pit TP-6 in a sample collected from beneath a drum that was unintentionally ruptured during test pit excavation. Toluene was present in the sample at a concentration of 1.5%; benzene, ethylbenzene and xylenes were also detected in the sample at lower concentrations. Elevated levels of chlorinated hydrocarbons (ranging as high as 670 ppb), including trichloroethene, 1,1,2,2-tetrachloroethane and 1,2-dichloroethene, were detected in samples TP-2-21 or TP-9-20. Each of these samples were collected at depths of greater than 20 feet, and both test pits were located along the southeastern edge of the landfill.

During the Phase II RI, the highest concentrations of VOCs were detected in subsurface soil sample 09-MW7-23, collected at a depth of 44-46 feet. This sample, which exhibited a strong solvent odor, contained 1,2-dichloroethene and vinyl chloride at concentrations of 3,100 ppb and 350 ppb, respectively. Individual chlorinated compounds were also detected in other subsurface soil samples at relatively low concentrations, ranging from 2 ppb to 15 ppb.

Aromatic compounds were also detected in Phase II subsurface soil samples, with total xylenes detected in samples 09-B07-06 and 09-B08-04 at concentrations of 4,500 ppb and 4,400 ppb, respectively. Other aromatic compounds, including benzene, toluene, chlorobenzene, ethylbenzene, and xylenes, were detected in samples 09-MW5-06 and 09-MW11-5.

Acetone (at 51 to 180 ppb) and 2-butanone (at 11 ppb) were also detected in the VOC analysis of Phase II subsurface soil samples. TCLP analyses conducted on three Phase II RI subsurface soil samples indicated that VOCs are not highly leachable from the soils.

Ground Water

Phase I RI ground water sample analyses identified the presence of chlorinated and aromatic VOCs in well 09-MW2S and the presence of chlorinated hydrocarbons in well 09-MW3D.

During the Phase II RI, aromatics, chlorinated hydrocarbons, 1,2-dichloropropane, acetone and 2-butanone were detected in ground water samples. Chlorinated VOCs were detected in six shallow wells and five deep wells. The highest concentrations detected in shallow wells were present in well 09-MW6S, with 1,2-dichloroethene, trichloroethene, and tetrachloroethene at concentrations of 70 ppb, 5 ppb, and 5 ppb, respectively. Chlorinated VOCs were generally detected at higher levels in the deep wells, with the highest levels measured in the sample collected from well 09-MW7D. Vinyl chloride, 1,2-dichloroethene, 1,2-dichloroethane and trichloroethene were detected at concentrations of 7,000 ppb, 28,000 ppb, 320 ppb, and 1,200 ppb, respectively in sample 09-MW7D. Chlorinated VOCs were also detected in deep wells 09-MW3D and 09-MW9D and a single chlorinated compound, 1,2-dichloroethene, was detected at an estimated concentration of 2 ppb at well 09-MW13D.

Aromatic VOCs were detected in six shallow and one deep monitoring well, with total aromatic VOC concentrations ranging as high as 629 ppb (at 09-MW11S). Benzene was detected at levels ranging from 1 to 11 ppb, and chlorobenzene was present in well 09-MW11S at a concentration of 620 ppb. Toluene, ethylbenzene and total xylenes were also detected in ground water samples.

Other VOCs detected in shallow ground water samples include 1,2-dichloropropane and chloroethane at concentrations of 940 ppb (09-MW6S) and 5 ppb (09-MW8S), respectively. Other VOCs detected in deep ground water samples include 1,2-dichloropropane (230 ppb), acetone (3,000 ppb) and 2-butanone (4,500 ppb), all detected at 09-MW7D.

<u>Leachate</u>

During the Phase I RI, four leachate samples were collected along the shoreline at the toe of the landfill. Leachate sample S9-4 was the only sample that contained volatile organic contaminants. Chlorinated aliphatic hydrocarbons were detected in this sample, including 1,1,2,2-tetrachloroethane (2 ppb), 1,2-dichloroethane (10 ppb), 1,2-dichloroethene (21 ppb), and vinyl chloride (3 ppb). Leachate samples were not collected during the Phase II RI.

<u>Surface Water</u>

A Priority Pollutants GC scan of a single surface water sample during the Confirmation Study did not identify the presence of any volatile organic compounds.

Surface water samples were not collected during the Phase I RI. However, six VOCs were detected in surface water samples collected from the Allen Harbor Watershed during Phase II investigations. These included acetone (at 7 to 13 ppb), methylene chloride (at 2 to 5 ppb), carbon disulfide (at 2 to 44 ppb), 1,2-dichloroethene (at 6 ppb), trichloroethene (at 2 ppb) and 1,1,2,2-tetrachloroethane (at 3 ppb). The chlorinated VOCs were all detected in sample SW10, collected from an area of tidal influence at the toe of the landfill face in Allen Harbor. In samples SW09, also collected from the toe of the landfill face, carbon disulfide was the only VOC detected, at an estimated concentration of 2 ppb.

Sediment

Volatile organics were not detected in a composite sediment sample collected during the Confirmation Study.

During Phase I investigations, four sediment samples were collected at locations corresponding to leachate sample locations. Chloroform was detected in one of the sediment samples at a concentration of 16 ppb. Acetone, a common laboratory contaminant, was detected in two of the four sediment samples at concentrations ranging from 60 ppb to 110 ppb.

Four VOCs were detected in sediment samples collected from the Allen Harbor Watershed during Phase II investigations. 2-Butanone was present in four samples at concentrations ranging from 34 ppb to 160 ppb. Methylene chloride (in SD08 at 190 ppb), benzene (in SD09 at 7 ppb), and toluene (in SD04 at 3 ppb) were each detected once in downstream samples. Benzene was the only VOC detected in the sediment samples collected from the toe of the landfill face at sample stations 09 and 10.

Clams

During the Confirmation Study, one composite clam sample from the first sampling round exhibited methylene chloride and 1,1,1-trichloroethane, each at concentrations of 50 ppb. Clam samples exhibited benzene, toluene, chlorobenzene, and xylenes during the second sampling round at concentrations ranging from 1 ppb to 8 ppb.

2.6.2 Semi-Volatile Organic Compounds (SVOCs)

Surface Soils

The composite surface soil sample collected during the Confirmation Study exhibited fluoranthene at an estimated level of 200 ppb. No other SVOCs were detected in the sample.

Polynuclear aromatic hydrocarbons (PAHs), a subset of SVOCs, were present throughout the Phase I RI surface soil samples. The highest PAH levels were detected in surface soil samples TP-3-00 and TP-8-00. Other SVOCs detected in the Phase I surface soil samples included phthalate esters, dibenzofuran and benzoic acid.

PAH compounds, phthalate esters, and phenols were the SVOC compounds detected in surface soils during the Phase II RI. Again, PAH compounds were prevalent throughout the site. Total PAH concentrations ranged from 237 ppb (09-B05-01) to 878,810 ppb (09-B07-01). The range in total carcinogenic PAH concentrations, as represented by the same two samples, was 92 ppb to 424,300 ppb. Four samples contained total PAHs at concentrations exceeding 100 ppm while thirteen samples contained PAHs at concentrations of greater than 10 ppm. PAH contamination was most prevalent in the southern portion of the site (09-B01-01, 09-B03-01 and 09-MW5-01), although the highest PAH concentrations were detected at 09-B07-01, in the northern portion of the site.

Phthalate esters were detected infrequently and generally at low concentrations. Bis(2-ethylhexyl)phthalate was the most commonly detected phthalate ester, present at concentrations ranging from 60 ppb to 2,300 ppb. It was present in two samples at concentrations exceeding 1,000 ppb (09-SS05 and 09-MW11-01).

Phenols were detected in two surface soil samples. 4-Methylphenol and 2,4-dimethylphenol were present in 09-B07-01 at 570 ppb and 370 ppb, respectively, while pentachlorophenol was present in 09-MW11-01 at 98 ppb.

Other SVOCs detected in surface soil samples include dibenzofuran, carbazole and 1,2,4-trichlorobenzene. The greatest concentrations of dibenzofuran and carbazole (which ranged as high as 8,400 ppb and 18,000 ppb, respectively) were detected at the same locations which exhibited the highest PAH and carcinogenic PAH concentrations (09-B01-01, 09-B03-01, 09-B07-01, and 09-MW5-01). 1,2,4-Trichlorobenzene was detected in only one sample (09-MW11-01) at an estimated concentration of 240 ppb.

It should be noted that the presence of PAHs in two of the Phase II soil samples, 09-B01-01 and 09-B07-01, may be associated with asphalt particles which were present in the samples.

Subsurface Soils

Polynuclear aromatic hydrocarbons (PAHs) were present throughout the Phase I RI subsurface soil samples. The highest subsurface soil PAH levels were detected in samples TP-6-02 (collected from beneath a ruptured drum), TP-4-12 (exhibited visible contamination), and TP-7-06 (exhibited visible contamination). Other SVOCs detected in subsurface soils included phthalate esters, dibenzofuran, phenols, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, and benzoic acid. These compounds were generally detected infrequently and at low concentrations, except at sample location TP-6-02.

During the Phase II RI, SVOCs detected in subsurface soil samples included PAHs, phthalate esters, dibenzofuran and carbazole. PAHs were detected in nine samples at concentrations exceeding 10 ppm. The highest concentrations were detected in visibly contaminated subsurface soil samples 09-MW5-04, 09-MW5-06, and 09-MW11-05 (281 ppm, 6,025 ppm and 569 ppm, respectively). Total carcinogenic PAH concentrations at these three locations were 135 ppm, 2,064 ppm and 202 ppm, respectively.

Bis(2-ethylhexyl)phthalate, di-n-butylphthalate and butylbenzylphthalate were the most commonly detected phthalate esters in subsurface soil samples. Concentrations of these compounds ranged from 97 ppb to 10,000 ppb, 52 ppb to 410 ppm and 58 ppb to 13,000 ppb, respectively. The highest concentrations of phthalate compounds were detected in subsurface soils collected from soil boring 09-B04 and monitoring well borings 09-MW6 and 09-MW7, each located in the central portion of the landfill.

Dibenzofuran and carbazole were each detected in eleven of the twenty-one subsurface soil samples at concentrations ranging from 47 ppb to 120,000 ppb and 41 ppb to 160,000 ppb, respectively. The highest concentrations of these compounds were detected in subsurface soil samples collected from monitoring well borings 09-MW5S and 09-MW11S.

Other SVOCs detected infrequently in subsurface soils include phenols, dichlorobenzene, 2,2'-oxybis(1-chloropropane) and n-nitrosodiphenylamine.

The highest SVOC concentrations were detected in three subsurface soil samples collected from monitoring well borings 09-MW5S and 09-MW11S. The highest concentrations are associated with areas of visible contamination and waste materials.

Ground Water

During the two rounds of ground water sampling conducted during the Phase I RI, low concentrations of four SVOCs were detected. Naphthalene and 2-methylnaphthalene were detected in well 09-MW2S during the first sampling round only, at concentrations of 5 ppb and 2 ppb, respectively. Bis(2-chloroethyl)ether was detected in well 09-MW3D at 2 ppb in the first round and bis(2-chloroethyl)ether and bis(2-chloroisopropyl)ether were both detected in well 09-MW3D in the second round at concentrations of 3 ppb.

Phenols, dichlorobenzenes and PAHs were the most commonly detected SVOCs in Phase II RI ground water samples. Phenols were detected in nine of the nineteen monitoring well samples, with the highest concentrations detected in wells 09-MW5S and 09-MW6S. Dichlorobenzenes were detected in three shallow wells, with the highest levels detected in well 09-MW11S. PAH compounds were detected in five monitoring wells, with the highest total PAH concentration (209 ppb) detected at monitoring well 09-MW5S. The soil samples collected from well boring 09-MW5 also exhibited the highest PAH levels for subsurface soils. Other SVOCs detected infrequently and a low concentrations in Site 09 ground water samples include bis(2-chloroethyl)ether, 2,2'-oxybis(1-chloropropane), n-nitroso-di-n-propylamine, hexachloroethane, dibenzofuran, 4-nitroaniline, and phthalate esters.

Leachate

SVOCs were detected in two of the four Phase I RI leachate samples. Pentachlorophenol, bis(2-ethylhexyl)phthalate, and benzoic acid were detected in sample S9-4 at levels of 4 ppb, 2 ppb, and 2 ppb, respectively. Various PAHs were detected in sample S9-2. Leachate samples were not collected during the Phase II RI.

Surface Water

During the Confirmation Study, phenol was detected in only one surface water sample. A GC Priority Pollutants scan did not identify the presence of any other SVOCs.

Surface water samples were not collected at Site 09 during the Phase I RI. During Phase II RI activities, two SVOCs, diethyl phthalate and di-n-butylphthalate, were each detected at 1 ppb in one surface water sample, SW06, from the Allen Harbor Watershed. However, SW06 was collected from a location northeast of Site 09, adjacent to Site 07, and therefore is not considered to be reflective of contaminants associated with Site 09. No SVOCs were detected at sample stations 09 and 10, located at the toe of the landfill.

Sediment

The composite sediment sample collected during the first sampling round of the Confirmation Study exhibited phenanthrene, fluoranthene, and pyrene at levels of 90 ppb, 160 ppb and 150 ppb, respectively.

Most of the Phase I sediment samples contained numerous PAHs. Phthalates and benzoic acid were also detected.

During the Phase II RI, PAHs were detected in five of the sediment samples at total concentrations ranging from 160 ppb to 78,550 ppb. The highest PAH concentrations were detected at sediment sample location SD09, located at the toe of the landfill face. Several phenolic compounds were infrequently detected at concentrations ranging from 460 ppb to 1,300 ppb. Other SVOCs detected include dibenzofuran (840 ppb), diethylphthalate (260 ppb), carbazole (1,900 ppb) and bis(2-ethylhexyl)phthalate (in five samples at concentrations ranging from 110 ppb to 1,100 ppb). Of these, dibenzofuran and carbazole were detected in sample SD09. No SVOCs were detected in sample SD10, also located at the toe of the landfill.

Clams

No SVOCs were detected in the composite clam sample collected during the initial round of Confirmation Study sampling. Fluoranthene and pyrene were detected at concentrations of 75 ppb and 56 ppb, respectively, in only one of the three clam samples collected during the second round of the Confirmation Study.

2.6.3 Pesticides/PCBs

Surface Soils

During the Confirmation Study, surface soil samples were collected and analyzed for PCBs during two sampling rounds. During the first sampling event, PCBs were detected at concentrations ranging from 140 ppb to 1,090 ppb. PCBs were detected in surface soil samples at levels ranging from 200 ppb to 1,500 ppb during the second sampling round.

During the Phase I RI, pesticides were detected in only two of the eighteen surface soil samples at Site 09. The pesticide beta-BHC was detected in surface soil samples TP-6-00 and B-09-01-00 at concentrations of 11 ppb and 21 ppb, respectively. PCB compounds were detected in six of the surface soils collected during the Phase I RI. Concentrations of PCBs detected in the Site 09 surface soils ranged from 240 ppb to 4,900 ppb.

Results of the Phase II surface soil investigation indicate that both pesticides and PCBs are present in the site surface soils at low concentrations. Pesticides were detected in all but two of the surface soil samples collected at the site during the Phase II RI. Pesticide compounds that were detected in more than half of the surface soil samples collected include 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, and gamma chlordane.

The PCB Aroclor-1260 was detected in eight of the surface soil samples at concentrations ranging from 17 ppb to 30,000 ppb. PCBs were detected in five of the eight surface soil samples collected from the northern portion of the landfill.

Subsurface Soils

Results of the Phase I RI subsurface soil sampling indicated that pesticides were present in three samples and PCB compounds were present in four samples of the eighteen subsurface soil samples collected. Pesticide compounds detected in the subsurface soil samples included beta-BHC in samples TP-4-12 and TP-5-06 at concentrations of 44 ppb and 42 ppb, respectively, and 4,4'-DDD and 4,4'-DDE at concentrations of 110 ppb and 66 ppb, respectively. PCBs were detected in subsurface soil samples collected from test pits TP-5, TP-6, TP-8, and TP-9 at concentrations ranging from 290 ppb to 1,100 ppb.

Results of the Phase II RI subsurface soil sampling at Site 09 indicated that both pesticides and PCBs are present in the subsurface soils. Pesticides were detected in all but two of the twenty-two subsurface soil samples collected across the site. The highest concentrations of pesticides were detected at subsurface soil samples 09-B03-03 (4,4'-DDE at 890 ppb), 09-B08-04 (4,4'-DDD at 320 ppb), 09-MW5-06 (4,4'-DDD at 620 ppb), and 09-MW7-06 (4,4'-DDD at 430 ppb).

PCBs (Aroclor-1254 and 1260) were detected in twelve of the subsurface soil samples collected at nine locations at the site. PCBs were detected at concentrations ranging from 22 ppb (09-MW10-09) to 3,400 ppb (09-MW6-08). Of the nine locations at which PCBs were detected in subsurface soils, only four of these locations (09-B08, 09-MW5, 09-MW8, and 09-MW11) also contained PCBs in the surface soils.

Ground Water

Pesticides/PCBs were not detected in either of the Phase I RI monitoring well sampling events, although PCBs were detected in a water sample collected from test pit 3 (TP-3) at a concentration of 20 ppb. Phase II ground water samples exhibited three pesticide compounds. Specifically, dieldrin was detected in samples from monitoring wells 09-MW6S, 09-MW9S, and 09-MW9D at concentrations of 0.0021 ppb, 0.0024 ppb, and 0.0024 ppb, respectively. 4,4'-DDD was detected in the sample from monitoring well 09-MW9S at a concentration of 0.0037 ppb, while alpha chlordane was detected in monitoring well sample 09-MW5S at a concentration of 0.012 ppb. No PCB compounds were detected in the Site 09 ground water samples.

Leachate

Pesticides were not detected in the Phase I RI leachate samples. The PCB Aroclor 1260 was present in samples S9-1 and S9-2 at concentrations of 1.5 ppb and 13 ppb, respectively. Leachate samples were not collected during the Phase II RI.

Surface Water

A GC Priority Pollutants scan of one surface water sample during the Confirmation Study did not identify the presence of pesticides or PCBs in the sample.

Surface water samples were not collected at Site 09 during the Phase I RI. Heptachlor epoxide represents the only pesticide which was detected during Phase II surface water sampling of the Allen Harbor Watershed. Heptachlor epoxide was present in surface water sample SW08 at an estimated trace concentration of 0.011 ppb. PCBs were not detected in the Phase II surface water samples.

Sediment

During the Confirmation Study, PCBs were detected in the first sampling round at concentrations ranging from 40 ppb to 190 ppb.

Pesticides/PCBs were not detected in the Phase I sediment sampling event. During the Phase II RI, pesticides were detected in each of the ten Allen Harbor Watershed sediment samples. The most heavily impacted sediment sample was SD09 which was collected from the toe of the landfill face, along the landfill's southern edge. Sediment sample SD09 exhibited some of the highest detected pesticide levels including the following: heptachlor epoxide (8.1 ppb), dieldrin (2.9 ppb), 4,4-DDD (32 ppb), endosulfan sulfate (3 ppb), endrin ketone (9.4 ppb), and alpha chlordane (0.5 ppb). The PCB Aroclor 1260 was detected in sediment samples SD04, SD07, and SD10 at concentrations of 87 ppb, 60 ppb, and 590 ppb, respectively.

Clams

PCBs were not detected during first round Confirmation Study clam samples. During the second round of the Confirmation Study, PCB Aroclor-1254 was detected at concentrations ranging from 8 ppb to 28 ppb.

2.6.4 Inorganics

Surface Soils

During the Confirmation Study, the maximum detected concentrations of inorganic analytes detected in surface soil samples during the two sampling rounds include: arsenic at 21 ppm, barium at 160 ppm, cadmium at 26.1 ppm, chromium at 100 ppm, copper at 1,300 ppm, lead at 33,700 ppm, manganese at 1,060 ppm, mercury at 3.5 ppm, nickel at 250 ppm, selenium at 0.96 ppm, silver at 7.5 ppm, and zinc at 3,000 ppm.

During the Phase I RI, chromium and lead were detected in all of the surface soil samples. The levels of chromium detected in each of the surface soil samples ranged from 3 ppm to 955 ppm. The levels of lead detected in each of the surface soil samples ranged from 3.8 ppm to 8,710 ppm.

All but one of the Phase II surface soil samples contained at least one analyte at concentrations above the NCBC background range. Each of the TAL analytes was detected in surface soils at a level exceeding the NCBC background range. The highest concentration of lead detected was 4,320 ppm.

Subsurface Soils

In general, the results of the Phase I RI subsurface soil analyses were similar to the surface soil sample results. Lead was detected in all but one of the subsurface soil samples at concentrations ranging from 3.5 ppm to 1,440 ppm.

Results of the Phase II RI indicate that each TAL inorganic analyte, except for thallium, was detected in at least one of the twenty-two subsurface soil samples at concentrations above the NCBC background ranges.

Ground Water

Results of the Phase I RI ground water sampling indicated that antimony, cadmium, and lead were present at elevated levels. Antimony and cadmium were detected in the sample from well 09-MW2S at concentrations of 71 ppb and 5.2 ppb, respectively. Lead was detected in monitoring well 09-MW2S at a concentration of 19.1 ppb and in monitoring well 09-MW4S at a concentration of 25.5 ppb. Elevated levels of antimony (159 ppb), cadmium (32 ppb), chromium (63 ppb), lead (1,380 ppb) and mercury (2.3 ppb) were also detected in a water sample collected from test pit 3 (TP-3) in the Phase I RI.

During the Phase II RI, samples from eleven shallow ground water monitoring wells and eight deep wells were analyzed for TAL metals. In addition, samples from three monitoring wells were also analyzed for filtered metals. Results of the Phase II ground water sampling indicate that inorganic analytes are present in the Site 09 ground water. The only inorganic analytes which were not detected in the site ground water include beryllium and mercury. Comparison of the filtered vs. non-filtered sample results indicate that the inorganic concentrations in the filtered samples are primarily equivalent to or slightly less than the concentrations of the non-filtered samples. Comparison of the Phase I and Phase II analytical data reveals a significant reduction in analyte concentrations in the Phase II results which may be attributed to the low flow sampling methodology employed during the Phase II ground water sampling program.

Leachate

In general, each of the inorganic analytes was detected in at least two or more of the four Phase I RI leachate seep samples. Leachate seep samples were not collected during the Phase II RI.

Surface Water

During the Confirmation Study, two rounds of surface water sampling were conducted. The maximum detected concentrations of inorganic analytes in the two rounds include: cadmium at 83.6 ppb, chromium at 9.1 ppb, lead at 12.7 ppb, manganese at 60 ppb, mercury at 230 ppb, selenium at 190 ppb, silver at 100 ppb, and zinc at 180 ppb.

Surface water samples were not collected during the Phase I RI. Results of the Phase II inorganic analyses reveal that inorganic analytes are present in the surface water of the Allen Harbor Watershed. Most of the TAL analytes were detected in at least one of the surface water samples. Analytes that were not detected in any of the surface water samples include: antimony, beryllium, mercury, nickel, selenium, silver, thallium, zinc and cyanide. Generally, inorganic analyte concentrations increased with proximity to Allen Harbor, with the stations located at the toe of the landfill face (SW09 and SW10) exhibiting some of the highest concentrations of inorganics. Sample SW08 also exhibited elevated inorganic levels, with the highest concentrations of aluminum (724 ppb), arsenic (5.7 ppb), cadmium (5.8 ppb) and lead (23.9 ppb).

Sediment

Copper, lead, nickel, and zinc were common inorganic contaminants to all of the sediment samples during both sampling rounds of the Confirmation Study.

During the Phase I RI, arsenic, beryllium, cadmium, chromium, copper, lead, nickel, silver, and zinc were common contaminants to all of the sediment samples. Comparatively higher concentrations of metals were identified at sample location S9-2 than at surrounding locations.

During the Phase II RI, all of the inorganic constituents, with the exception of antimony and cyanide, were detected in at least one of the sediment samples from the Allen Harbor Watershed. The most heavily impacted samples were SD05, located approximately 2,000 feet northeast of Allen Harbor Landfill, and SD09, collected at the toe of the landfill face. Sample SD09 exhibited the highest concentrations of the following analytes: lead at 121 ppb, mercury at 44 ppb, silver at 1.8 ppb, thallium at 3.5 ppb and vanadium at 71.8 ppb.

Clams

During the Confirmation Study, cadmium, copper, and zinc were common inorganic contaminants to all of the clam samples collected during the two sampling rounds.

2.6.5 TCLP Analysis

During the Phase I RI, four soil samples collected from test pits TP-2, TP-3, TP-8 and TP-9 were submitted for TCLP analysis. The analytical results indicated that low levels of volatile organics, semivolatile organics and inorganics were leachable from the soils under the conditions of the analysis.

During the Phase II RI, a total of three soil samples from Site 09 were collected and submitted for TCLP analyses. These samples included the soil borings for monitoring wells 09-MW8 and 09-MW11 (09-MW8-04 and 09-MW11-05) and soil boring 09-B03 (09-B03-03). The analytical results of these samples indicate that the only contaminant detected above regulatory action levels as identified on the TCLP list was the inorganic constituent cadmium in the sample 09-MW8-04. Cadmium was detected at a level of 2.67 mg/l.

2.7 Risk Assessment Pilot Studies (Allen Harbor Studies)

A study of Allen Harbor has been conducted separately from the Remedial Investigations but is worthy of consideration in the RI/FS process. The scope of these studies, presented briefly in Section 2.5.4, is further described here along with a summary of the conclusions made from the studies.

In 1988, the USEPA's Environmental Research Laboratory (ERLN) at Narragansett, Rhode Island, and the Naval Ocean Systems Center (NOSC), entered into a Memorandum of Agreement (MOA) to develop cooperative research and monitoring activities for conducting marine and estuarine ecological risk assessments. Under this agreement, case studies were developed to characterize the risk of Navy hazardous waste disposal sites that could affect aquatic ecosystems.

The first case study developed under the MOA was the Risk Assessment Pilot Study (RAPS) conducted at NCBC Davisville. A phased approach was developed to provide information regarding the ecological risks posed by the RI/FS sites, particularly Allen Harbor Landfill and Site 07 - Calf Pasture Point, to Allen Harbor and Narragansett Bay. Phase I (NOSC, 1991) involved the collection and collation of environmental data characterizing the ecology, natural resources, sediment, and water quality of Allen Harbor relative to Narragansett Bay. This information was used to develop a preliminary ecological risk assessment of the harbor. Based on the findings of Phase I, a Phase II (ERLN, 1993) was conducted to evaluate the relative impacts of the NCBC sites, surface runoff from the surrounding land, and boating and marine activities conducted in the harbor on the marine system. Phase III (ERLN, 1994) was conducted to quantify the biological effects and ecological risks directly associated with Allen Harbor Landfill.

The technical approach taken in Phase I included collecting information about the physical and chemical attributes of the site contaminants (waste site characterization); the distribution of contaminants within Allen Harbor (exposure assessment); and the effects of these contaminants on ecological systems within the harbor (effects assessment).

The waste site characterization portion of the study centered primarily on identifying chemicals emanating from Sites 07 and 09 and utilized Phase I RI results including analytical results for samples of water flowing from seeps on the face of the landfill, the sediments surrounding these seeps, and ground water from monitoring wells and a test pit. In combination with the general descriptions of the material disposed at the sites, the range and quantities of environmental contaminants which might be transported into the harbor and nearby Narragansett Bay were identified.

The spatial distributions of specific contaminants of concern were quantified through extensive field sampling efforts. Sampling efforts focused on intertidal and subtidal sediments in Allen Harbor. Additionally, several stations in the West Passage of Narragansett Bay were sampled to address questions of contaminant movement and to provide reference comparisons. Water-column samples were also obtained inside and outside the harbor for chemical and bacteriological analyses. Tissue residues of contaminants in several resident biota were quantified to provide information regarding the levels of exposure actually experienced by organisms. Native bivalves, including the quahog, *Mercenaria mercenaria*, the soft-shell clam, *Mya arenaria*, the oyster, *Crassostrea virginica*, and an infaunal polychaete, *Nephtys incisa*, were obtained both within and outside of Allen Harbor for comparative purposes.

The ecological impacts of contaminants within Allen Harbor were evaluated through a combination of field sampling, field experimentation, and laboratory assays. Native *Mercenaria mercenaria, Mya arenaria, and Crassostrea virginica* were sampled for population abundance, individual condition, and histopathological effects. The blue mussel, *Mytilus edulis*, was deployed at several stations to address the effects of water quality on physiological condition and growth. Finally, the toxicity of sediments within Allen Harbor and at stations in Narragansett Bay was determined in the laboratory using both standard amphipod (*Ampelisca abdita*) bioassays and biomarker tests under development at ERLN.

Information collected during the waste site characterization, and exposure and effects assessments were synthesized into a preliminary assessment of ecological risk to Allen Harbor. Two approaches were used to characterize risk. The first involved calculation of risk quotients as the ratio of contaminant-specific exposure concentrations to effects benchmark concentrations for single contaminants. In this process, field measurements of sediment and water column contaminant concentrations were compared with published measures of sediment and water quality. The second approach compared the results of all biological and chemical assessments conducted for Allen Harbor with those obtained for stations in Narragansett Bay proper. The intent was to evaluate conditions in Allen Harbor within the context of the larger bay system as a whole.

Risk quotients (RQ) calculated for Allen Harbor sediments ranged in magnitude from much less than 0.1, to as high as 47 for the maximum detected level of DDT. The major risk to benthic systems derives primarily from pesticides, PCBs, and selected metals and PAHs. The Phase I study concluded, however, that there was no clear association of this risk with Sites 07 and 09. Based upon the small number of RQs calculated for Allen Harbor surface waters, the ecological risks associated with water-borne contaminants appeared to be minimal.

Although the results of waste characterization activities indicated the landfill to be a potential source of toxicologically important contaminants to the harbor, there was no clear association of observed impacts with proximity to the landfill. Of particular interest were the observations that contaminant exposures and biological effects were often most severe at the southern end of the harbor, farthest removed from the landfill and Calf Pasture Point. Other potential sources of contamination of the harbor were known to exist. For instance, based on surrounding land use, surface runoff of water into Allen Harbor from the surrounding land was viewed as a potential contaminant source. Additionally, Allen Harbor supports an active marina for the Town of North Kingstown, on its eastern shore, and is a popular anchoring spot for day trips by local boaters. A second marina, serving the Quonset Davisville Yacht Club, is located on the southwest shore of the harbor. Fuel leakage, dispersion of hull antifoulant paints, and septic wastes resulting from this intense boating and marina activity were suspected to potentially impact harbor quality. To clarify the potential role of Sites 07 and 09 on the observed impacts to Allen Harbor, Phase II activities were intended to partition contamination and toxicity among these three potential sources: Allen Harbor Landfill, surface runoff from the surrounding land, and boating and marina activities conducted within the harbor.

The main focus of Phase II activities involved assessment of exposure and effects associated with the three potential sources indicated above through implementation of a temporal and spatial sampling plan which took advantage of the seasonal nature of boating activities in Allen Harbor. This was accomplished through collection of field samples of sediment and water, and subsequent quantification of contaminant levels and biological effects.

A second component of Phase II involved further examination of the hemopoietic neoplasia (Hn) observed in Allen Harbor *Mya arenaria* during Phase I. Because harbor *Mya* displayed high rates of Hn relative to Narragansett Bay stations, the possibility existed that Allen Harbor could be acting as a source of the disease. To address this question, a one-time survey of *Mya neoplasia* was conducted throughout the West Passage of Narragansett Bay. Samples of *Mya* were collected at 20 stations, and evaluated in the laboratory for rate of infliction within each subpopulation.

Additionally, research was conducted to identify chemical compounds which could potentially be used to identify and quantify sources of contaminant input to Allen Harbor. This effort involved a survey of existing inventories of materials disposed of in the landfill, and analyses of selected sediment samples to evaluate potential input from sources other than the landfill, including sewage, road runoff, atmospheric, and petroleum sources.

The Phase II study concluded that its results implicated both the landfill and surface water runoff from land surrounding Allen Harbor to be significant contributors to chemical exposure and biological effects in the harbor. The highest levels of chemical and toxicity input were attributed to runoff from the Spink Neck storm drain, located at the southern end of Allen Harbor. Impacts from seasonal boating and marine activity were relatively minor. Specifically with respect to Allen Harbor Landfill, sediment contaminants indicated that landfill sources, along with runoff sources, contributed the highest level of pollutant input to the harbor. Tissue residues of PCBs, DDT, and chromium were statistically higher in indigenous ribbed mussels collected from the landfill than those from runoff stations. Based on the *Mya* neoplasia survey, percentages of Hn greater than 5% were found in eight of the eleven stations less than 5 km from the landfill and the highest percentages of Hn were diagnosed in *Mya* from stations less than 10 km from the landfill. Although the report concluded that there appeared to be some association between neoplastic disease and proximity to the landfill, *Mya* from two stations within or immediately adjacent to the harbor displayed little or no Hn.

Phase III of the study involved a quantification of biological effects and ecological risks directly associated with Allen Harbor Landfill. Exposure-response assays were conducted of landfill seep waters, sediments, and sediment extracts using a variety of marine species and endpoints. Resulting data were used to develop models describing biological response as a function of exposure concentration. These models were used to quantify risks posed by the landfill to pelagic and benthic ecological systems in Allen Harbor using a joint probability method. A laboratory evaluation of the relationship between landfill contaminants and neoplasia development in the soft-shell clam also was conducted.

Exposure-response models were developed for landfill seep water and sediment extracts using data obtained for a number of species and short-term toxicological endpoints. A toxic unit (TU) approach was used. In a general sense, a toxic unit is simply the ratio of a contaminant concentration to some biological benchmark concentration for that chemical and is often expressed as a percentage. As such, it is arithmetically similar to the risk quotient developed in Phase I of the study. In Phase III, however, contaminant-specific TUs were summed to derive a single, aggregated metric (ΣTU) of chemical contamination for each unique environmental sample. This approach assumes additivity in the toxic actions of contaminants in complex mixtures.

Using a joint probability method, upper-bound probabilities of risk ranging between 0.24 and 0.69 were estimated for landfill seep water, with similar values calculated for storm runoff sources. Although these estimates indicate the potential for negative ecological impact associated with both landfill and runoff sources, actual risks to the harbor pelagic system would be expected to be lower than these estimates suggest, because both seep and runoff water would be diluted substantially upon mixing. Whole landfill sediments were not toxic to organisms tested in the laboratory, but sediment extract models suggested risks of up to 0.75 to benthic organisms with contaminant bioavailability taken into account. No statistical relationships were observed between landfill exposure media and soft-shelled clam neoplasia, although the experiment was not conclusive because conditions may have compromised treatment effects.

2.8 Summary of Contaminant Fate and Transport

A contaminant fate and transport analysis was initially conducted as a part of the Phase I RI and incorporated in the Initial Screening of Alternatives (TRC, 1993b). Subsequently, information obtained during the Phase II RI was incorporated into the contaminant fate and transport analysis and a revised discussion was presented in the Draft Phase II RI Technical Report (TRC, 1993e).

Potential routes of migration, contaminant persistence and observed contaminant migration were considered in evaluating the fate and transport of the site contaminants identified during the RI investigations.

In general, of the environmental media investigated at Site 09, surface soils and ground water have the greatest potential for off-site migration. Typically, contaminants in surface soils can migrate or be carried off-site by surface runoff (resulting from precipitation), by being sorbed to windblown dust, and by site visitors via adherence to vehicle tires, shoes, etc. Based on current site use, dust generation, tracking and surface runoff are expected to be minimal given the presence of the current mixture of shrubs, small trees and grasses over the landfill. If the surface is disturbed during implementation of a remedial action, these migration mechanisms could be of more importance. Contaminants can also migrate from the surface soils through leaching (by infiltration of precipitation) and subsequent transport by ground water, by volatilization to ambient air or by uptake by plants or animals.

Subsurface soils are also unlikely to be transported off-site unless exposed by excavation. The primary mode of transport of chemicals in subsurface soil would be leaching and ground water transport.

Contaminants in ground water may potentially migrate toward Allen Harbor to the east and south and toward the marsh area to the southwest of the site. The ground water at Site 09 flows radially from the landfill mound towards Allen Harbor and the wetlands.

The following sections examine the presence of Contaminants of Concern (COCs), as identified during the Human Health Risk Assessment process (TRC, 1993e), across the site in combination with the potential migration pathways to provide an under standing of contaminant persistence and potential for migration at the site. The discussions below are presented with respect to individual contaminants or contaminant groups based on environmental fate data such as water solubility, vapor pressure, Henry's law constants, organic carbon-water partition coefficients (K_{oc}), octanol-water partition coefficients (K_{ow}) and half-life in water.

Volatile Organic Compounds

In general, VOCs were detected infrequently and at low concentrations in site soils. The volatile COCs detected in Site 09 soils include 1,1,1-trichloroethane, 2-butanone, acetone, benzene, chlorobenzene, chloroform, ethylbenzene, tetrachloroethene, toluene, trichloroethene, and xylenes. The principal mechanism for removal of VOCs is through volatilization, based on Henry's law constants which range from 4.3×10^{-5} atm/mole (acetone) to 2.7×10^{-2} atm/mole (tetrachloroethene). Biodegradation removal processes are compound-specific, as are adsorption processes. With the exception of xylenes, all of the volatile COCs are fairly soluble in water with solubilities of 150 mg/l (tetrachloroethene) to being miscible (acetone). Therefore, the primary migration pathway is expected to be leaching to the ground water, with volatilization a secondary pathway. Xylenes in soil have a lesser tendency to partition from organic media into water. Therefore, transport of particulates off-site in surface water run-off and wind erosion may represent additional migration pathways of interest for xylenes in surface soils.

Of the eleven volatile COCs identified in soil, seven were identified as COCs in ground water including acetone, benzene, chlorobenzene, ethylbenzene, toluene, trichloroethene, and xylenes. Volatile COCs detected in ground water but not in soil include 1,2-dichloroethane, 1,2-dichloroethene (total), 1,2-dichloropropane, and vinyl chloride. While the solubilities of these four additional VOCs are similar to those detected in soil and ground water, their log K_{ow}s are slightly lower indicating a slightly enhanced potential for migration into ground water.

Semi-Volatile Organic Compounds

Twenty-four SVOCs were identified as COCs in surface soil at Site 09. In subsurface soil, an additional five SVOCs were selected as COCs. The list of soil COCs includes 17 PAHs, four phthalates, two chlorinated benzenes, one phenol, one propane, TCDD and three additional constituents. The two chlorinated benzenes, one phthalate, one phenol, and one propane were identified as COCs in subsurface but not surface soil. In general, the PAHs and phthalates were associated with the highest detection frequencies and concentrations. It should be noted that phthalates are common laboratory contaminants and are widespread in the environment (ATSDR, 1987; ATSDR, 1989).

SVOCs, particularly PAHs, are generally persistent in the environment due to their complex chemical nature. SVOCs are generally characterized by high boiling point, low vapor pressure, and low solubility (except for lower molecular weight PAHs, phenols and phthalates). The solubilities of phthalate COCs range from 0.4 mg/l for bis(2-ethylhexyl)phthalate to 1,100 mg/l for diethyl phthalate. The solubility of the chlorinated benzenes is within the same range as that of the phthalates, while the solubility of 4-methylphenol (20,000 mg/l) is considerably higher. TCDD is relatively insoluble (1.9×10^{-5} mg/l).

SVOCs, in general, have moderate to high log K_{oc} and log K_{ow} values indicating a relative affinity for organic materials in solid and liquid phases. The log K_{oc}s and log K_{ow}s of PAHs and phthalates are generally greater than 3, with many greater than 5. The log K_{oc} and log K_{ow} values for TCDD are 6.7 and 6.6, respectively. While chlorinated benzenes have slightly lower log K_{oc} and log K_{ow} values, phenols have a much greater tendency for partitioning into water than do either the PAHs, phthalates, or TCDD.

Of the 29 semivolatile COCs in soil, ten were identified as COCs in ground water including four small molecular weight PAHs, two chlorinated benzenes, one highly soluble phthalate (diethyl phthalate), one phenol, one propane, and two other constituents. Six additional COCs were identified in ground water including 2-methylphenol, 2,4-dimethylphenol, 4-nitrophenol, bis(2-chloroethyl)ether, bis(2-chloroisopropyl)ether, and phenol. In general, the SVOCs identified as COCs in ground water are more soluble (and therefore more likely to migrate into ground water) than the SVOCs identified as COCs in soil only.

With the exception of the more soluble SVOCs identified as COCs in ground water, migration of SVOCs from soil to ground water is not likely to be a primary migration route of concern. Off-site transport of these less soluble SVOCs may be possible through dust generation at the soil surface and through soil transport in surface water runoff. SVOCs in soil are more likely to persist than VOCs, but are less likely to persist than pesticides/PCBs or inorganics.

Pesticides/PCBs

Seventeen pesticides and one PCB (Aroclor 1260) were identified as COCs in surface and/or subsurface soil at Site 09. Pesticides and PCBs have a strong affinity for organic materials in soils, which tends to reduce their mobility. In addition, many pesticides and PCBs are persistent in the environment (i.e. have large half-lives). Of the 18 pesticide/PCB COCs in soil, only one (dieldrin) was identified as a COC in ground water. Two other pesticides were detected in ground water (4,4'-DDT and alpha-chlordane) but at extremely low frequencies. The much smaller number of pesticides/PCBs in ground water indicates that the migration of these constituents from soil into ground water is limited. The primary migration pathways for pesticides and PCBs in soil include transport of surface soil particulates in surface water runoff and via wind erosion.

Inorganic Analytes

Many metals have a strong affinity for soils (particularly clay particles and organic matter in soils) which reduces their mobility. High pH can increase the mobility of certain metals. The presence of inorganic analytes at Site 09, particularly the naturally occurring elements, was examined in the context of site background concentrations, as presented in Table 2-4. Site background samples were collected as composite samples from unimpacted areas at Sites 02, 07, 09, and 10 and wooded areas near site Sites 06, 11, and 13 during the Phase II RI. The inorganic COCs in surface soil which appear elevated above site background in one or more samples include aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, nickel, selenium, silver, vanadium, and zinc. The inorganic COCs which appear elevated above site background in subsurface soil are the same as for surface soil, with the exception of aluminum, cyanide, and selenium, and the addition of thallium.

The inorganic COCs in ground water include aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, silver, thallium, vanadium, and zinc. The presence of a number of these inorganics in surface and subsurface soils indicates migration from soil to ground water may have occurred. However, it should be noted that a significant reduction in ground water concentrations of these contaminants was noted from the Phase I to the Phase II RI. This reduction is believed to be due to the use of low flow sampling methods, and the Phase II RI data are thought to be more reflective of the actual inorganic concentrations. Therefore, the migration of inorganics from the soil to the ground water may not be as significant as might be suspected on the basis of Phase I RI data alone.

TCLP Analysis

The TCLP analyses of the soil samples indicate that the only contaminant above regulatory levels as identified on the TCLP list (40 CFR 261.24) was the inorganic constituent cadmium in sample 09-MW8-04. Cadmium was detected at a level of 2.67 mg/l, which slightly exceeds the TCLP list regulatory level of 1 mg/l. This finding suggests that cadmium could potentially be leached from the soil into the ground water at Site 09.

2.9 Summary of Human Health Risk Assessment

The Human Health Risk Assessment conducted for Site 09 (TRC, 1993e) evaluated the contaminants of potential concern, assessed potential exposure pathways and chemical toxicity, and characterized potential risks to human health posed by the site. Both Phase I RI and Phase II RI data were used to characterize the human health risks. Exposure doses were developed based on the geometric mean of chemical concentrations (mean) as well as on the basis of the maximum detected chemical concentration (Reasonable Maximum Exposure or RME). Potential human health exposure scenarios evaluated include the following:

- Scenario 1 (Future Construction Worker) - Exposure of adult workers to subsurface soils (via dermal contact, ingestion and inhalation) for a one-year period, assuming construction of commercial or residential buildings; and

- Scenario 2 (Future Recreational) - Exposure of children/youths (ages 2 to 18 years) to surface soils (via dermal contact, ingestion and inhalation) through future use of the site. This site use scenario conforms with the future recreation and conservation use proposed in the Comprehensive Reuse Plan for NCBC Davisville.

- Scenario 3 (Future Commercial/Industrial Worker) - Exposure of adult employees to ground water through ingestion under future use of the site.

Human health risks were presented with regard to potential cancerous or non-cancerous (systemic) effects from the contaminants of concern. Cancer risks are presented in scientific notation, where a lifetime risk of 1×10^{-4} represents a lifetime risk of one in ten thousand. The calculated cancer risk is compared to the acceptable cancer risk range (1×10^{-4} to 1×10^{-6}) for evaluating the need for remediation, as stated in 40 CFR Part 300. A cancer risk of 1×10^{-6} is considered as the point of departure for determining risk-based remediation goals. Non-carcinogenic risks are represented by a summation of hazard quotients, which is referred to as the hazard index (HI). HI values exceeding unity (1) indicate the potential for non-cancer health effects. Therefore, the cancer risk and HI ratios that constitute a potential concern are those greater than 1×10^{-6} and 1, respectively.

Cancer and non-cancer risk estimates for Site 09 are summarized in Table 2-5. For Scenario 1 (construction scenario), a potential cancer risk range of 4×10^{-6} to 1×10^{-4} and a non-cancer hazard index ratio range of 0.3 to 3 were estimated based on exposures to subsurface soils. Exposure to arsenic, beryllium and carcinogenic PAHs accounts for the majority of the cancer risks while exposure to antimony accounts for the majority of the non-cancer hazard index values.

Exposure to surface soils under Scenario 2 (future recreational) is estimated to result in a potential cancer risk range of 1×10^{-5} to 6×10^{-4} and a non-cancer hazard index ratio of less than unity. Exposure to arsenic, beryllium, carcinogenic PAHs, and 2,3,7,8-TCDD accounts for the majority of the cancer risks.

Exposure to ground water under Scenario 3 (future commercial/industrial) is estimated to result in a potential cancer risk range of 2×10^{-4} to 5×10^{-2} and a non-cancer hazard index ratio range of 2 to 40. Exposure to a relatively wide range of contaminants including inorganics (arsenic and beryllium), VOCs (1,2-dichloroethane, 1,2-dichloropropane, trichloroethene, and vinyl chloride), SVOCs (bis(2-chloroethyl)ether and 1,4-dichlorobenzene) and pesticides (dieldrin) accounts for the majority of the cancer risks. Exposure to antimony, manganese and 1,2-dichloroethene accounts for the majority of the non-cancer hazard index ratios.

2.10 Summary of Ecological Risk Assessment

Ecological risks were assessed based on an evaluation of potential receptors identified through the ecological characterization of the Allen Harbor Watershed and Site 09, and the detected levels and bioavailability of contaminants in environmental media. Terrestrial risks were characterized based on site-specific biological observations and surface soil data. Aquatic risk was assessed for the watershed. A "weight of evidence" approach was used in which information generated from exposure and ecological effects assessments, field observations and a toxicity quotient (TQ) evaluation are used to provide an overall weight of evidence concerning the nature of risks. As with the human health HI ratios, when the calculated TQ value exceeds unity (one), a potential for environmental risks exists.

Risks to benthic invertebrates were assessed based on sediment quality criteria derived from equilibrium partitioning on a station-by-station basis; an estimate of metal bioavailability based on a ratio of Simultaneously Extracted Metal (SEM) to Acid Volatile Sulfide (AVS); a comparison to NOAA ER-L and ER-M values (Long and Morgan, 1990); and direct observations on the freshwater benthos in the watershed. Risks to water column organisms were estimated based on a comparison to ambient water quality criteria. An exposure model was used to estimate risks to mink from exposure to PCBs in the sediments. Risks to small mammals and birds were estimated on the basis of calculated TQ values.

On the basis of these evaluations, it was concluded there is a potential for ecological risk, due to exposure to metals, in the Allen Harbor Watershed based on the following:

- the frequency and magnitude with which concentrations in freshwater stations and sediments at the toe of the landfill face exceeded natural concentration ranges;
- SEM:AVS ratios which are greater than 1 at a freshwater wetland stations and at the toe of the landfill face indicating the potential for bioavailability of metals;
- the results of the shrew, hawk, and robin exposure models which indicate the potential for risk associated with metal uptake through the food chain at Site 09;
- the exceedance of NOAA ER-M values for several metals by orders of magnitude at a freshwater wetland station and two stations at the toe of the landfill face; and
- the toe of the landfill face exhibited toxicity in anphipod toxicity testing.

There is also some potential for risk based on the pesticides detected in sediment samples collected at the toe of the landfill face which exceeded station-specific sediment quality criteria and, at one of the two locations, the ER-M for DDD. However, there is little risk from PCBs in the Allen Harbor Watershed based on the mink and tern foraging models.

Within the Allen Harbor marine environment, it was concluded that marine communities in Allen Harbor do not exhibit ecological risk based on the population status of indigenous shellfish, observations on the wildlife of associated salt marsh, the results of toxicity testing on Allen Harbor sediments, the results of the tern and mink exposure foraging models, and the results of chemical testing in the harbor.

3.0 SCREENING OF TECHNOLOGIES AND DEVELOPMENT OF ALTERNATIVES

Based on the available site information, potential remedial actions can be identified. Initially, remedial action objectives are developed in order to set goals for protecting human health and the environment early in the alternative development process. General response actions are then developed to address the objectives. Remedial technologies and process options associated with the general response actions are identified and screened to eliminate those that are not technically implementable and to identify those that offer the optimum combination of effectiveness, implementability and cost.

3.1 Superfund Program Expectations

Key to the development of remedial alternatives for a landfill site is the consideration of USEPA's expectations for remediation of such sites under the Superfund program. Since many CERCLA landfill sites share similar characteristics, the USEPA has established a number of expectations regarding the types of remedial alternatives that should be developed for detailed analysis at such sites. These expectations are listed in the National Contingency Plan [NCP, 40 CFR 300.430(a)(1)] and in USEPA's guidance on Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites (USEPA, 1991a), where they are outlined as follows:

- The principal threats posed by a site should be treated wherever practicable, such as in the case of remediation of a hot spot.
- Engineering controls, such as containment, will be used for waste that poses a relatively low long-term threat or where treatment is impracticable.
- A combination of methods will be used as appropriate to achieve protection of human health and the environment. An example of combined methods for a landfill site would be treatment of hot spots in conjunction with containment (capping) of the landfill contents.
- Institutional controls, such as deed restrictions, will be used to supplement engineering controls, as appropriate, to prevent exposure to hazardous wastes.
- Innovative technologies will be considered when such technologies offer the potential for superior treatment performance or lower costs for performance similar to that of demonstrated technologies.

- Ground water will be returned to beneficial uses whenever practical, within a reasonable time, given the particular circumstances of the site.

These expectations will guide the development of remedial action objectives and potential remedial alternatives for the Allen Harbor Landfill site.

3.2 Development of Preliminary Remediation Goals (PRGs)

Prior to the development of Remedial Action Objectives (RAOs), preliminary remediation goals (PRGs) are developed and evaluated with respect to site contaminant levels. Existing contaminant levels are compared to Applicable or Relevant and Appropriate Requirements (ARARs), To-Be-Considered guidance (TBCs), and risk-based PRGs to identify the extent of contamination requiring remediation. Also included in the evaluation is the role of environmental risks and the application of models to predict the potential for migration of soil contaminants to the ground water. Such an evaluation also provides for the identification of any hot spot areas of contamination which may require separate consideration from the control of the landfill as a whole.

3.2.1 Comparison of Contaminants to ARARs/TBCs

There are several media which must be considered in terms of potential remediation at the Allen Harbor Landfill site. Soil, ground water, and surface water/sediment must be considered in the development of a final remedy for the site. These media are evaluated separately against appropriate chemical-specific ARARs/TBCs below. A more detailed identification and evaluation of potential chemical-specific ARARs/TBCs is presented in Appendix A.

Soil Contamination Evaluation

In evaluating PRGs applicable to soil contaminant levels, available state and federal standards and guidelines were used as ARARs/TBCs. The only standards/guidance levels applicable to soils which have been identified are those related to PCB and lead contamination. Therefore, these levels were used as the basis for this evaluation.

As presented in Table 3-1, TSCA includes a PCB Spill Cleanup Policy (Subpart G, 40 CFR 761.120 through 761.135) which establishes a PCB cleanup level of 10 ppm for soils to a minimum depth of 10 inches in nonrestricted access areas. This level is applicable to spills of materials containing PCBs at concentrations of 50 ppm or greater which occurred after May 4, 1987. While not applicable to PCB contamination at Allen Harbor Landfill, this cleanup level is to be considered in the remedial evaluation of PCB-contaminated surface soils at the site. The State of Rhode Island Department of Environmental Management (RIDEM) Rules and Regulations for Solid Waste Management Facilities define solid waste as including any soil, debris, or other material with a concentration of 10 ppm or greater PCBs, while the Rules and Regulations for Hazardous Waste Management define Type 6 - extremely hazardous waste as including waste which contains 50 ppm or greater PCBs. These definitions are also considered with respect to soil contamination at Allen Harbor Landfill.

With respect to lead contamination, the USEPA has developed an Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02) which sets forth an interim lead soil cleanup level of 500 to 1,000 ppm, based on residential exposures. RIDEM considers a safe lead level in soil to be under 300 ppm. These guidance values will be considered in the evaluation of surface soil contamination at the site.

Table 3-1 provides a comparison of maximum detected surface soil contaminant levels to associated guidance levels. Figure 3-1 presents the locations of surface soil samples which contained lead or PCBs at levels exceeding federal and state guidance levels.

As indicated in Figure 3-1, PCBs were detected at a level exceeding 10 ppm at only one location during the Phase I and Phase II RIs. The surface soil sample collected at the location of monitoring well 09-MW11 exhibited the PCB Aroclor 1260 at a level of 30 ppm. Lead levels in five Phase I RI and seven Phase II RI surface soil samples exceeded the state guidance level of 300 ppm. Additionally, the four Phase I RI sediment samples collected from along the shoreline exhibited elevated lead levels. In general, the sample locations at which the state guidance level was exceeded are located across the site. The upper range of the federal interim cleanup level for lead (1,000 ppm) was exceeded at Phase I RI surface soil sample locations S9-5 (8,710 ppm) and TP9-8 (3,070 ppm) and at Phase II RI sample location 09-B01 (4,320 ppm).

Three of the Phase I RI sediment sample locations also contained lead at a level exceeding 1,000 ppm.

Ground Water Contamination Evaluation

As discussed in Appendix A, an evaluation of existing ground water quality information at Site 09 indicates that, due to the site's proximity to Allen Harbor, the ground water is brackish and would not be suitable as a potential source of drinking water. Therefore, based on USEPA guidance (USEPA, 1991a), federal Ambient Water Quality Criteria (AWQC), environmental considerations (i.e., effects on biological receptors) and prevention of plume expansion will be used to develop PRGs. AWQC are non-enforceable guidelines used by States to set water quality standards for surface water and are considered with respect to ground water quality when ground water may discharge to surface water that is used for fishing or shellfishing. State Water Quality Standards (WQS), as established under the RI Water Pollution Control Law (RIGL, Title 46, Chapter 12), may also be considered in the development of PRGs. AWQC and state WQS will be used as the focus for this evaluation. Environmental considerations are evaluated further in Section 3.2.3.

A comparison of detected ground water contaminants to federal and state water quality criteria is presented in Table 3-2. Several volatile organic contaminants detected in Phase II RI deep ground water samples, including 1,2-dichloroethane, trichloroethene, 1,1,2-trichloroethane, vinyl chloride, and 1,2-dichloroethene (total) exceeded the AWQC. For the shallow ground water samples, tetrachloroethene was the only volatile organic contaminant detected at levels exceeding AWQC. No semi-volatile organics were detected in either shallow or deep ground water at levels exceeding AWQC. PCBs were detected in a shallow ground water sample collected from test pit 9 during the Phase I RI at a level exceeding AWQC. Numerous inorganic analytes were detected in both shallow and deep ground water samples at levels exceeding AWQC. These include arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, and manganese.

Surface Water/Sediment Contamination Evaluation

Federal Ambient Water Quality Criteria and state Water Quality Standards are also applicable to the evaluation of surface water quality. Table 3-3 compares federal AWQC and state WQS to the quality of surface water samples collected in the immediate vicinity of the landfill during the Phase II RI. Table 3-4 compares federal AWQC and state WQS to the quality of leachate seep samples collected during the Phase I RI. No ARARs/TBCs were identified as being potentially applicable to sediments. Sediment quality is further evaluated with respect to environmental risk-based considerations in Section 3.2.3.

Only surface water sample stations 09 and 10 were included in the surface water evaluation. Sample stations 09 and 10 are the only stations directly associated with Allen Harbor Landfill, with the samples collected at the toe of the landfill. As indicated in Table 3-3, the only constituents detected at these sample stations at concentrations exceeding federal AWQC or state WQS were arsenic and manganese. Both arsenic and manganese were detected at surface water station 10 at concentrations of 4.2 ppb and 137 ppb, respectively. The water quality criteria for protection of human health based on fish ingestion only are 0.0175 ppb for arsenic and 100 ppb for manganese.

Numerous constituents were detected in the Phase I leachate seep samples at concentrations exceeding water quality criteria, as indicated in Table 3-4. Pentachlorophenol and PCBs were the only organic contaminants detected at levels exceeding water quality criteria. Pentachlorophenol, detected at an estimated concentration of 10 ppb, exceeded the chronic marine aquatic life criterion (7.9 ppb) but not the acute criterion (13 ppb). PCBs, detected at a level of 13 ppb exceeded the acute and chronic marine aquatic life criteria (10 ppb and 0.03 ppb, respectively) as well as the water quality criterion for protection of human health based on fish ingestion only (0.000079 ppb). Inorganics detected in leachate seep samples at concentrations exceeding water quality criteria include arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc and manganese.

3.2.2 Human Health Risk-Based Considerations

As described in the NCP [40 CFR 300.43(e)(2)(i)(A)(2)], "The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available...". The 10^{-6} starting point indicates USEPA's preference for setting preliminary remedial goals at the more protective end of the acceptable 10^{-4} to 10^{-6} risk range for Superfund remedial actions. Site-specific and remedy-specific factors are then taken into consideration in the determination of where within the 10^{-4} to 10^{-6} risk range the cleanup standard for a given contaminant will be established. For the purpose of this evaluation, the risk-based preliminary remedial goals which correspond to a 10^{-6} risk are calculated.

Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991a) provides additional guidance on the development of preliminary remediation goals (PRGs). One of the initial steps in development of PRGs is the identification of the most appropriate future land use for the site so that the appropriate exposure pathways, parameters and equations can be used to calculate PRGs. At Site 09, based on the Comprehensive Base Reuse Plan, the most appropriate future land use is as a recreational/conservation area. Therefore, exposures to surface soils, the only exposure pathway evaluated under the Human Health Risk Assessment for the future recreational exposure scenario, will guide the development of PRGs. Exposures to ground water are not anticipated, based on the site's proximity to Allen Harbor and the potential brackishness of the ground water. Based on the sharp topographic drop to the shoreline of the site and the gravelly nature of the shoreline area, recreational exposure to shoreline sediments is not anticipated to pose a major exposure pathway.

As a further guide to determining the media and chemicals of potential concern at a site, the OSWER directive "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (USEPA, 1991b) states that "where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts." At Site 09, the cumulative carcinogenic risk to an individual based on reasonable maximum exposure to surface soils for a future recreational use exceeds 10^{-4}. No non-carcinogenic soil contaminants resulted in hazard index (HI) values greater than unity. Therefore, evaluation of risk-based preliminary remediation goals is appropriate.

Those surface soil contaminants which contribute an individual cancer risk of greater than 1×10^{-6} under the reasonable maximum exposure scenario for future recreational use and for which no ARARs/TBCs have been identified include arsenic, beryllium, carcinogenic PAHs, and 2,3,7,8-TCDD equivalents. The specific PAHs which were identified include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. The maximum detected concentrations of these contaminants in surface soils, the associated reasonable maximum exposure cancer risks and the surface soil preliminary remediation goals calculated for these contaminants based on a 1 x 10^{-6} cancer risk level are presented in Table 3-5. Additional information used in the development of risk-based preliminary remediation goals is presented in Appendix B.

The surface soil contaminant levels for each of the surface soil sample locations were compared to the risk-based cleanup levels presented in Table 3-5. PAHs, arsenic and beryllium were each detected across the site at levels exceeding the PRGs in Phase I and Phase II RI surface soil samples. Figure 3-2 indicates the locations of the samples which contained contaminants at levels exceeding the PRGs.

In evaluating the potential applicability of the calculated risk-based cleanup levels to site remediation, it should be noted that the calculated risk-based cleanup level for arsenic is less than the upper range of 8.1 ppm detected for arsenic in site-specific background samples. Also, while 2,3,7,8-TCDD equivalents were noted in the risk assessment as being associated with an individual cancer risk greater than 1 x 10^{-6}, this risk estimate was driven by use of the analytical detection limits (for samples in which 2,3,7,8-TCDD equivalents were not detected) in the risk calculations (per standard risk assessment methodology) rather than on the basis of actual detected values. Therefore, as indicated in Table 3-5, the maximum detected concentration of 2,3,7,8-TCDD equivalents is actually less than the PRG.

3.2.3 Environmental Risk-Based Considerations

As discussed in Section 2.10, a potential for environmental risk due to exposure to 4,4'-DDD and metals in the Allen Harbor Watershed has been identified based on a weight of evidence approach to risk evaluation. Since the Allen Harbor Watershed is comprised of a large area, including areas upgradient of Allen Harbor Landfill and areas which may be affected by Site 07 - Calf Pasture Point, an evaluation of the potential impacts of Allen Harbor Landfill alone is important in determining preliminary remediation goals associated with the landfill itself. Therefore, an evaluation of soil-related risks and sediment-related risks for the landfill my be appropriate.

A potential for risks to terrestrial organisms exists based on the results of the terrestrial exposure models which utilize surface soil data for the site. Therefore, surface soils are a potential source of ecological risk at Site 09.

For sediments, a comparison of sediment contaminant levels for sediment samples SD09 and SD10 (refer to Section 3.2.1 for the basis on which these locations were selected) to NOAA ER-L (Effects Range-Low) and ER-M (Effects Range-High) values (Long and Morgan, 1990) is presented in Table 3-6. ER-L and ER-M values represent the lower 10th percentile (ER-L) and median (ER-M) concentrations at which effects have been observed or predicted, based on Long and Morgan's evaluation. While not intended to be used as criteria by which to judge whether sediments are contaminated, ER-L and ER-M values provide initial screening criteria and may be used to assess contaminant levels in a qualitative way. Comparison of contaminant levels to ER-L and ER-M values was just one consideration in the overall evaluation of ecological risk. For instance, PAHs were detected in sediments at levels exceeding ER-M values but, in the overall weight of evidence approach to evaluating environmental risks, PAHs were not considered to pose a significant ecological risk. Therefore, the comparison provided in Table 3-6 is useful in providing an indication of the relative contamination of sediments associated with Allen Harbor Landfill but must be considered with respect to other available evidence of potential risk. As indicated in Table 3-6, ER-M values were exceeded for PAHs, 4,4'-DDD and inorganics at sampling station SD09 and for PCBs and metals at SD10.

It should be noted that the areal extent of sediments in the vicinity of sample locations SD09 and SD10 is very limited. In general, the landfill toe is characterized by the presence of a hard substrate (e.g., gravel), and would be suitable habitat for organisms which live on hard substrates but not suitable for borer-type organisms. Therefore, the exposure pathway exhibited by the sediment areas is very limited.

Ecological risks were not identified for the Allen Harbor marine environment, based on the Ecological Risk Assessment (TRC, 1993d).

3.2.4 Contaminant Migration Considerations

Another consideration in the development of remedial response objectives is the potential for contaminant migration, especially as it applies to subsurface soil contamination. Since exposures to subsurface soils are not included in the expected future use exposure scenario (future recreational use) for the site, potential leaching of subsurface contaminants to the ground water is the greatest concern with respect to the existing subsurface soil contamination. To evaluate the potential for contaminant leaching to be a major factor in contaminant migration, the "Unnamed Model" described in Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples (USEPA, 1989a) was applied to existing site data.

The unnamed model is a variation of the Summers Model, also described in the above-referenced document. The Summers Model is basically a mass balance in which the concentration of contaminant leached from a contaminated area multiplied by the volumetric rate of infiltration over the area of contamination plus the upgradient (incoming) ground water contaminant concentration (assumed to be equal to zero) multiplied by the volumetric rate of ground water flow entering the site will equal the ground water contaminant concentration exiting the site multiplied by the volumetric rate of ground water flow exiting the site (which is equal to the volumetric rate of infiltration plus the volumetric rate of ground water flow into the site). The Summers Model is applied to the entire area of the site, assuming that the entire site area is equally contaminated.

The unnamed model uses the same approach but applies it to a unit area of the site. Therefore, the rate of infiltration is applied to a 1-square-foot area in determining the volumetric rate of infiltration and the ground water flow velocity is applied to an area which is a unit dimension wide (1 foot) but equal to the saturated thickness of the aquifer in terms of height. This approach is more applicable to the characteristics of a landfill where hot-spot areas may exhibit high levels of contamination which are not characteristic of the landfill as a whole.

In both models, the maximum allowable ground water contaminant concentration leaving the site (or the unit area) is assumed to equal the Maximum Contaminant Level. Since the ground water at Site 09 is thought to be brackish, with no potential use as a source of potable water, this approach is conservative. The volumetric flow rate of infiltration is estimated based on known precipitation and infiltration values and the volumetric flow rate of ground water entering the site is estimated based on information obtained during the Phase I and II RIs. Using published octanol-water partition coefficients (K_{OW}) and organic carbon soil concentrations measured during the RI, the maximum allowable concentration of a contaminant in the ground water (equal to the MCL) can be related to the maximum allowable contaminant concentration in the soil in the saturated zone. The maximum concentration of a contaminant adsorbed to the soil in the unsaturated zone can then be back-calculated using the mass-balance approach described above. The calculations conducted for Site 09 are described in detail in Appendix C.

The results of the unnamed model calculations for Site 09, as presented in Appendix C and summarized in Table 3-7, indicate that the majority of the contaminants detected in unsaturated surface and subsurface soil samples do not exceed the estimated maximum allowable contaminant concentration in unsaturated soils which is protective of ground water quality (based on use of the MCL as the maximum allowable ground water concentration). The only exception to this statement is the presence of toluene in the unsaturated soil sample collected from test pit 6 during the Phase I RI. However, this sample was collected from beneath a drum which was accidentally punctured during the investigation. Approximately one gallon of liquid leaked from the drum and the sample was subsequently collected from beneath the drum. A number of samples exceeded the estimated maximum saturated contaminant concentrations, with the sample collected from a depth of 10- to 12-feet at monitoring well 5 (09-MW5-06) exhibiting the highest contaminant levels. The maximum detected saturated zone contaminant levels are all less than the estimated maximum allowable unsaturated zone contaminant levels, which indicates that if permanent dewatering of these areas was possible, they would not be expected to pose a concern with respect to potential leaching.

Another consideration in the potential migration of contaminants from subsurface soils is the information provided by the Toxicity Characteristic Leaching Procedure (TCLP) analyses conducted during both the Phase I and Phase II RIs on subsurface soil samples. Of the seven samples collected and analyzed for TCLP (Phase I RI samples TP-02-08-S, TP-03-06-S, TP-08-06-S, and B-09-02-02S and Phase II RI samples 09-MW8-04, 09-MW11-05 and 09-B03-03), only one sample, 09-MW8-04, exhibited a constituent at a level exceeding maximum allowable TCLP levels (see Table 3-8). Cadmium was detected in the TCLP analysis of 09-MW8-04 at a level of 2.67 ppm (maximum allowable = 1 ppm). It is of interest to note that one of the samples collected for TCLP analysis during the Phase II RI, 09-MW11-05, was a relatively contaminated unsaturated soil sample, exhibiting some of the highest levels of semi-volatile organics as well as volatile organic, pesticide, PCB and inorganic contaminants, but the TCLP analysis did not detect any contaminants at levels exceeding acceptable TCLP levels. Therefore, available TCLP analyses support the unnamed model results in indicating that minimal leaching of contaminants from subsurface soils could be expected.

3.2.5 Evaluation of Potential Hot Spots

Hot spots consist of highly toxic and/or highly mobile material and present a potential principal threat to human health or the environment. As described in Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites (USEPA, 1991b), excavation or treatment of hot spots is generally practicable where the waste type or mixture of wastes is in a discrete, accessible location of the landfill. A hot spot should be large enough that its remediation will significantly reduce the risk posed by the overall site, but small enough that it is reasonable to consider removal and/or treatment.

Typically, hot spots at landfill sites can consist of areas of drum disposal. Since only one drum was identified during the RI, drums are not considered to represent a potential principal threat at the Allen Harbor Landfill site.

No other potential hot spots were identified at Site 09. While elevated PAH levels are present in unsaturated and saturated subsurface soils at monitoring well location 09-MW5, the lack of potential exposures based on anticipated future site use and the minimal potential for contaminant migration of PAHs does not indicate that this contamination poses a principal threat.

Similarly, the detected levels of chlorinated solvents in monitoring well 09-MW7D are elevated in comparison to other ground water samples but, due to the lack of potential exposure to ground water, are not considered to pose a principal threat to human health. Although chlorinated organics were identified as potential contaminants of concern in surface water in the ecological risk assessment (TRC, 1993b), no significant ecological risks were associated with exposures to surface water in the Allen Harbor marine environment; therefore, no principal threat to the environment was identified either.

As discussed in Section 3.2.4, cadmium was detected in the TCLP analysis of a subsurface soil sample collected from the boring for 09-MW8 at a level (2.4 ppm) exceeding the federal TCLP limit (1 ppm). However, cadmium was not detected in either of the shallow or deep ground water samples collected from wells 09-MW8S or 09-MW8D. Therefore, remediation of this isolated location would not be considered to result in a significant reduction in the risk posed by the overall site, since risk estimates were not driven by the presence of cadmium in soils and since ground water at this location appears to be unaffected. Also, current EPA technical guidance (USEPA, 1993) states that the Toxicity Characteristic rule is not to be used to determine whether to undertake a cleanup action but rather to make decisions concerning the management of wastes generated during cleanup activities.

3.2.6 PRG Summary

Based on this analysis, remediation of surface soils must be considered on the basis of exceedances of ARARs/TBCs for lead and PCBs and based on the risks posed by surface soils to human health and the environment under the anticipated future recreational site use. ARAR/TBC levels may be used as PRGs for surface soils along with risk-based PRGs.

Subsurface soils pose no significant human health risks since the anticipated future use of the site does not involve exposures to subsurface soils. Modeling of the potential for contaminant migration from the subsurface soils indicates that unsaturated soils are of minimal concern, although contaminants in saturated soils may act as a continued source of ground water contamination.

Although no direct relationship between ground water quality and surface water or sediment quality impacts has been clearly established, concerns with respect to potential ground water contaminant migration exist, based strictly on a comparison of ground water contaminant levels to federal AWQC and state WQS (especially with respect to VOCs and metals). Also, the discharge of leachate seeps to surface water bodies is a potential concern, based on the presence of numerous constituents in Phase I leachate seep samples at levels exceeding AWQC and WQS. However, as discussed in Appendix A, AWQC and WQS must be evaluated along with environmental considerations in the development of ground water PRGs. Therefore, federal AWQC and state WQS will be used to identify potential contaminants of concern in ground water, but environmental considerations will factor into any evaluation of potential compliance with these standards.

For surface water itself, manganese and arsenic were the only constituents detected at levels exceeding water quality criteria in the water samples collected at the toe of the landfill face, and no significant risks to the marine environment were identified in the ecological risk assessment (TRC, 1993b). Therefore, while the potential for any continued discharge of contaminants to surface water is of concern, existing surface water quality does not appear to be significantly impacted.

Sediments have been identified as posing a potential environmental risk within the Allen Harbor Watershed. ER-M values could be considered as being representative PRGs for the sediments. While the sediment samples collected from the toe of the landfill face exceeded PRGs, the limited areal extent of sediment in this area must be considered. It is anticipated that remedial actions which address the landfill as a whole may also address the potential risks associated with the sediments at the toe of the landfill face.

3.3 Remedial Action Objectives

Based on an evaluation of the expectations of Superfund, as presented in Section 3.1 as well as the conclusions presented in Section 3.2.6, the Remedial Action Objectives developed to guide the implementation of a remedial response at the Allen Harbor Landfill site are as described below.

Unsaturated Soils/Waste

Surface soils currently pose a potential risk to human health and the environment and may be a source of contaminant migration due to surface water runoff. Subsurface unsaturated soils and waste materials do not appear to be of major concern with respect to leaching of contaminants based on the results of the leaching model (as described in Section 3.2.4). Therefore the remedial action objective for unsaturated soils/wastes is as follows:

- Minimize potential risks to human health and environment associated with exposure to surface soil contaminants, including contaminants detected at levels exceeding ARARs/TBCs, as presented in Table 3-1, and contaminants detected at levels exceeding risk-based cleanup levels, as presented in Table 3-5, as appropriate; and

- Minimize potential environmental impacts by minimizing off-site migration of surface soil contaminants.

The waste materials at Site 09 could also be of concern with respect to potential landfill gas generation. Landfill gas generation rates may be declining, based on the age of the landfill. Since an investigation of landfill gas was not conducted as part of the RI, however, the need for remedial action objectives to address the potential production of landfill gas cannot .be determined. However, the potential impacts of landfill gas generation will be considered in the evaluation of remedial alternatives for soils/wastes at Site 09 and requirements for further definition of landfill gas at the site will be specified, where appropriate.

Saturated Soils/Wastes

Saturated soils/wastes may provide a continued source of contamination to ground water; however, treatment of the saturated soils/wastes is not technically practicable. Currently, ground water contamination at Site 09 does not pose a threat to human health but may pose a threat with respect to potential environmental impacts resulting from contaminated ground water migration. Therefore, while no remedial action objectives specifically addressing saturated soils/wastes are identified herein, evaluations of the means of achieving the remedial action objectives for ground water, as described in the following section, will consider the potential contribution of saturated soils/wastes to continued ground water contamination.

Ground Water/Leachate

Ground water/leachate contamination may pose an environmental threat due to potential migration and discharge to the surrounding environment. While ground water is classified as GB and is expected to have no value as a potable water source due to brackish qualities, there is no existing regulatory mechanism to limit future ground water uses. Therefore, the remedial action objectives for ground water are as follows:

- Minimize the potential for future exposures to contaminated ground water due to on-site well installation; and
- Minimize potential environmental impacts which could be associated with the migration of contaminated ground water or leachate from the landfill area via surface seeps or subsurface migration to Allen Harbor or adjacent wetland areas.

Surface Water

Currently, no significant impacts to surface water resulting in unacceptable environmental risks have been identified in the immediate vicinity of Allen Harbor Landfill. Therefore, no remedial action objectives have been developed for surface water.

Sediment

Potential environmental risks associated with sediment contamination have been identified for sediments in the Allen Harbor Watershed. Sediments at the toe of the landfill face are the samples most directly impacted by the landfill. However, remediation activities associated with sediments (e.g., dredging) often cause significant disruption that can result in increased environmental risks. Therefore, the remedial action objective for sediment is as follows:

- Minimize potential environmental impacts associated with exposures to contaminated sediments at the toe of the landfill face to the greatest extent possible, without creating more significant adverse environmental impacts.

3.4 General Response Actions

General response actions are those remedial actions which will satisfy the Remedial Action Objectives. The first step in determining appropriate general response actions for the Allen Harbor Landfill site is an initial determination of the areas or volumes to which the general response actions may be applied. In determining these volumes/areas, consideration has been given to site conditions, the nature and extent of contamination, acceptable exposure levels, and potential exposure routes, as well as USEPA's stated objectives and expectations for the Superfund program (see Section 3.1).

In identifying the area or volume to which general response actions would be applicable at Allen Harbor Landfill, the entire landfill portion of the site (estimated to be approximately 13.5 acres in area) must be addressed to respond to the potential risks the site poses to human health via direct exposures. Initial volume calculations indicate that the landfill contains approximately 300,000 cubic yards of material, of which approximately 40,000 cubic yards is located within the saturated zone. The majority of fill within the saturated zone exists in the southern portion of the site.

The evaluation presented in Section 3.2.5 did not result in the identification of any hot spot areas. Surface soil samples with carcinogenic PAH, arsenic, and beryllium concentrations exceeding risk-based cleanup levels were located across the whole site (see Figure 3-2). Considering the volume and heterogeneity of the materials within the landfill, treatment of the entire landfill area would not be practicable based on economic, technological, and implementation factors. Based on this analysis, a general response action involving removal or treatment of hot spot areas has not been developed for the site.

Separate general response actions for soils/wastes, ground water/leachate and sediment have been selected to address the Remedial Action Objectives at Site 09. For soils/wastes, the lack of identification of hot spot areas and the technical impracticality of treating the entire landfill have resulted in the identification of the following general response actions:

- No-Action
- Limited Action
- Containment

This approach is consistent with the NCP's expectations for remedial actions at Superfund sites, as discussed previously in Section 3.1.

For ground water/leachate, the following general response actions have been identified:

- No-Action
- Limited Action
- Containment
- Extraction/Treatment/Discharge

For sediment, the following general response actions have been identified:

- No-Action
- Limited Action
- Containment

3.5 Identification and Screening of Technologies and Process Options

The general response actions are developed further through the identification and screening of remedial technologies which could potentially meet the remedial response objectives and PRGs. Following a screening of the remedial technologies on the basis of technical implementability, the process options associated with each technology are screened based on effectiveness, implementability, and cost. Representative process options are chosen for inclusion in the remedial alternatives developed for the site.

While technology and process option screenings were conducted in the Initial Screening of Alternatives Report (TRC, 1993b), the screening process is re-evaluated herein based on the results of the Phase II RI and the impact of those results on the Remedial Action Objectives for the site.

3.5.1 Technology Screening

The technology screening performed for Site 09 is presented for soil/waste in Table 3-9, for ground water/leachate in Table 3-10 and for sediments in Table 3-11. The tables include brief descriptions of the individual technologies or process options, and comments on their technical implementability. Technologies which are screened from further consideration are shaded in the technology screening tables. More detailed descriptions of the screening process and the technologies considered are provided in Appendix D.

3.5.2 Process Option Screening

Upon identification of those technologies which are technically implementable, the process options are further evaluated to allow the selection of representative process options to be used in the development of remedial alternatives. The process options are evaluated on the basis of effectiveness, implementability, and cost. The process option screening is presented for soil/waste, ground water/leachate and sediment in Tables 3-12, 3-13 and 3-14, respectively. The selected representative process options are indicated with a bullet in the process option screening tables. Table 3-15 summarizes the technologies and process options which passed the technology screening, with selected representative process options indicated with an asterisk. More details on the representative process option selection process are provided in Appendix D.

3.6 Remedial Alternative Development

The selected technologies and process options identified in Section 3.4.2 are combined in this section to form remedial alternatives. The developed range of alternatives is intended to provide a streamlined evaluation of possible remedial actions. The alternatives presented herein have been developed in accordance with the expectations of the Superfund program, as outlined within the NCP and previously described in Section 3.1. Rather than combining alternatives for the various media, the alternatives developed for each media will be evaluated separately to allow greater flexibility in determining the overall remedial action for the site. The remedial alternatives developed for soil/waste, ground water/leachate and sediment at Site 09 are presented in Table 3-16.

An initial screening of alternatives on the basis of effectiveness, implementability and cost was conducted in the Initial Screening of Alternatives Report (TRC, 1993b). Based on the initial screening of the alternatives which were developed on the basis of Phase I RI data alone, no alternatives were screened from detailed analysis. While the alternatives have been modified to some degree based on the incorporation of Phase II RI data within this report and the consideration of additional environmental media (e.g., sediment), all developed alternatives will undergo a detailed analysis herein.

4.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

Each of the remedial alternatives developed for the site, as presented in Section 3.6, are further defined and then undergo a detailed analysis. Following the detailed analysis of individual alternatives, a comparative analysis is conducted between alternatives.

4.1 Evaluation Criteria

The NCP defines nine evaluation criteria to be considered in the detailed analysis of alternatives. The evaluation criteria are divided into three groups: threshold criteria, which relate to statutory requirements that each alternative must satisfy; balancing criteria, which are the technical criteria that are considered during the detailed analysis; and modifying criteria, which are formally assessed after the public comment period. The nine criteria include the following:

Threshold Criteria

- Overall protection of human health and the environment;
- Compliance with applicable or relevant and appropriate requirements (ARARs);

Balancing Criteria

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability;
- Cost;

Modifying Criteria

- Community acceptance; and
- State acceptance.

When evaluating alternatives in terms of overall protection of human health and the environment, consideration is given to the manner in which site-related risks are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls. Long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs are given major consideration in determining the overall protection offered by each alternative.

The alternatives are assessed to determined whether they attain applicable or relevant and appropriate requirements (ARARs) under federal environmental laws and state environmental or facility siting laws. The identification of ARARs is a site-specific process which is dependent on the specific hazardous substances, pollutants, and contaminants at a site, the physical characteristics of a site and the remedial actions under consideration at a site. Therefore, it is an iterative process which requires re-examination throughout the RI/FS process, until a Record of Decision (ROD) is issued. A preliminary ARARs analysis is presented in Appendix A of this document. In the following alternative analyses, the individual remedial alternatives will be evaluated in detail to determine their compliance with ARARs/TBCs which are applicable to the specific media being addressed by the remedial action, and the potential impacts of ARARs/TBCs on the alternative's implementation.

An alternative that does not meet an ARAR may be selected as a remedial action under several circumstances, including the following:

- If the alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement;
- If compliance with the requirement will result in greater risk to human health and the environment than other alternatives;
- If compliance with the requirement is technically impracticable from an engineering perspective;
- If the alternative will attain an equivalent standard of performance through the use of another method or approach; or
- If the ARAR is a state requirement that the state has not consistently applied in similar circumstances.

Each alternative is also evaluated for long-term effectiveness and permanence, in which the magnitude of residual risk remaining from untreated waste or treatment residuals and the adequacy and reliability of containment systems and institutional controls is evaluated. The degree to which alternatives employ recycling or treatment to reduce toxicity, mobility or volume is assessed, including how treatment is used to address the principal threats at the site. The short-term effectiveness evaluation takes into consideration the short-term risks that might be posed to on-site workers, the surrounding community, or the environment during implementation, as well as the time until protection is achieved. The analysis of implementability considers the technical feasibility and administrative feasibility of implementation, as well as the availability of required materials and services. The cost analysis evaluates capital (direct and indirect) costs and annual operation and maintenance (O&M). The net present value of capital and O&M costs is presented for each alternative.

In selecting a remedial action, the following criteria must be considered. Each selected remedial action shall meet the threshold criteria, and thereby be protective of human health and the environment. Provided the remedy meets the threshold criteria, it shall also be cost-effective. The overall effectiveness of an alternative is determined by evaluating long-term effectiveness and permanence, reduction of toxicity, mobility or volume through treatment, and short-term effectiveness. The alternative is then evaluated with regard to cost to ensure that it is cost-effective. Each remedial action shall also utilize permanent solutions and alternative treatment technologies to the maximum extent practicable. This requirement is fulfilled by selecting the alternative that satisfies the threshold criteria and provides the best balance of trade-offs among alternatives in terms of the five balancing criteria, with an emphasis on long-term effectiveness and reduction of toxicity, mobility and toxicity through treatment.

4.2 Soil/Waste Alternative Individual Descriptions and Evaluations

4.2.1 Alternative S/W-1 - No Action Alternative Description

The NCP requires consideration of the no-action alternative; at a minimum it provides a baseline for comparison with other alternatives. This alternative would involve no remedial response activities with respect to soil/waste at Allen Harbor Landfill. No removal or treatment of contaminated media or control of source areas would be conducted and no minimization of potential risks associated with direct contact with on-site contaminants or erosion of contaminants would be achieved. Because remaining contamination would not allow for unlimited future use of the site, a five-year review of the no action decision would be required.

An evaluation of the no action alternative with respect to the evaluation criteria is presented below.

An evaluation of the no action alternative with respect to federal and state chemical-specific and location-specific ARARs/TBCs is presented in Tables 4-1 and 4-2, respectively. Since there are no actions involved in this alternative, action-specific ARARs/TBCs do not apply.

4.2.2 Alternative S/W-1 - No Action Alternative Evaluation

Overall Protection of Human Health and the Environment - The no action alternative offers no protection of human health and the environment, because it does not address potential risks through the elimination, reduction, or control of exposures to site contamination. It does not limit future use of the site, and therefore does not limit the potential for future exposures due to changes in site use. This alternative is not effective in the long-term or short-term. Alternative S/W-1 complies with location-specific ARARs but does not meet chemical-specific ARARs/TBCs.

Compliance with ARARs - Since this alternative does not address PCBs and lead in soils, state and federal chemical-specific ARARs/TBCs will not be met. State and federal location-specific ARARs/TBCs would be met by the no action alternative since this alternative involves no actions which could impact coastal or wetland areas. Since there are no actions involved in this alternative, action-specific ARARs/TBCs do not apply.

Long-Term Effectiveness and Permanence - The no action alternative offers no long-term effectiveness or permanence in addressing contamination at the site. The existing potential risks to human health and the environment would remain, with no controls provided to manage exposures to contaminants or wastes under potential future site use scenarios. Due to the residual risk which would be associated with the no action alternative, a five-year review of the no action decision would be required under the NCP.

Reduction of Toxicity, Mobility, or Volume through Treatment - The no action alternative does not include any treatment methods other than naturally occurring degradation or attenuation processes. Therefore, the alternative offers no significant reductions in the toxicity, mobility, or volume of contamination through treatment.

Short-Term Effectiveness - The no action alternative does not result in any increased short-term risks due to the lack of activities associated with its implementation. It does not offer any short-term reduction in potential risks to human health or the environment. Potential migration pathways would not be addressed, thereby continuing to allow potential contaminant migration due to surface water runoff into Allen Harbor or adjacent wetland areas. Remedial action objectives would not be achieved.

Implementability - The no action alternative would require no implementation other than a five-year review of the no action decision. Its implementation would not limit the future implementation of additional remedial actions.

Cost - The cost associated with the no action alternative would be the nominal cost associated with conducting the five-year review.

4.2.3 Alternative S/W-2 - Limited Action Alternative Description

Alternative S/W-2 was developed as a limited action option which provides no active source control but limits potential risks to human health through the construction of a perimeter site fence and implementation of deed restrictions. A chain-link fence would be placed around the perimeter of the site to limit site access. Warning signs would be placed on the fence to warn any trespassers of the potential hazards associated with existing site conditions. Along the eastern side of the site, the fence would be located along the top of the bank which faces Allen Harbor. If technically possible, the fenceline would also be extended into the water along the northeastern and southwestern boundaries of the site to prevent access to shoreline areas. The existing grade along the shoreline may limit the fence's constructability and effectiveness along the southwestern boundary. Deed restrictions would restrict future use and development of the site, thereby further limiting potential exposures to on-site contamination. Since the Allen Harbor Landfill has historically received industrial wastes, surface water discharge monitoring is required.

An evaluation of Alternative S/W-2 with respect to federal and state chemical-specific, location-specific, and action specific ARARs/TBCs is presented in Tables 4-1 through 4-3.

4.2.4 Alternative S/W-2 - Limited Action Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative S/W-2 provides a limited degree of protection of human health by limiting potential exposures to the site. It provides no additional protection of the environment.

Through fencing, the action would limit potential exposures due to direct contact with the majority of contaminated areas, although access to areas along the shoreline may be difficult to restrict, due to existing grades in that area. Deed restrictions would limit future site use and development, thereby providing protection against the development of additional contaminant exposure pathways.

While fencing would be designed and constructed to comply with ARARs/TBCs and storm water discharge monitoring would be conducted in accordance with ARARs/TBCs, this alternative would not comply with chemical-specific ARARs/TBCs concerning PCBs and lead in soils. It is effective in the short-term but would not prove as effective in the long-term as other more sophisticated source control actions.

Compliance with ARARs - Alternative S/W-2 does not address PCBs or lead in soils and therefore, does not meet chemical-specific ARARs/TBCs. Implementation of the fencing component of this alternative would be conducted in accordance with applicable location-specific ARARs, as noted in Table 4-2. In addition, ARARs/TBCs concerning wetland and coastal areas would be met by this alternative. Storm water discharge monitoring would be conducted in accordance with federal and state Pollutant Discharge Elimination System (NPDES and RIPDES) requirements, as noted in Table 4-3.

Long-Term Effectiveness and Permanence - Alternative S/W-2 relies on the limitation of access to the site to reduce risk from direct contact. Though fencing limits access, it may not be totally effective, especially along the shoreline, where access from the water is possible. Deed restrictions on access/development would require long-term enforcement to ensure their protectiveness. Since wastes will remain on-site above levels that allow for unlimited use and unrestricted exposure, a five-year review of Alternative S/W-2 would be required.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative S/W-2 provides no treatment of site contamination and therefore no associated reduction in contaminant toxicity, mobility, or volume. Site access restrictions would limit the potential contaminant exposure pathways associated with current or future site use.

Short-Term Effectiveness - Minimal short-term risks would result from the implementation of Alternative S/W-2. Routine construction activities would be required to install the perimeter fence. Any exposures to contaminated material during these activities could be limited through the use of personnel protective equipment. No off-site risks would result from the implementation activities. Erosion control measures could be employed to limit any run-off during the construction period. Implementation is estimated to require less than three months. Remedial response objectives regarding the minimization of risks to human health would be achieved but the minimization of potential environmental impacts would not be achieved.

Implementability - The construction of a fence would generally be easy to implement, since associated equipment and materials are readily available. Construction of a fenceline into the waters along the southwestern boundaries of the site may be difficult to implement, potentially requiring the fence to be tied into the existing slope along the shoreline in such a way that trespassers would be unable to breach the barrier. Deed restrictions would have to be incorporated into the property transfer process following base closure. However, implementation of site use and access restrictions could contradict the Comprehensive Reuse Plan, which specifies that the Allen Harbor Landfill area be set aside for recreational/conservation use. Implementation of Alternative S/W-2 would not be expected to limit the implementation of future remedial actions.

Cost - Costs associated with the implementation of Alternative S/W-2 would be those associated with fence placement and the establishment of land use restrictions. The cost of implementation for Alternative S/W-2 is estimated to include $53,000 in direct capital costs, $7,500 in indirect capital costs and $19,000 in annual operation and maintenance costs ($290,000 net present value). The present worth value of this alternative, including contingency, is estimated at $420,000. A detailed cost estimate is presented in Appendix E.

4.2.5 Alternative S/W-3 - Containment Alternative Description

Alternative S/W-3 was developed to meet the NCP's requirement for consideration of an alternative which utilizes containment with little or no treatment and to meet the Superfund expectations regarding the remediation of landfill sites. This alternative provides no active remediation but limits potential risks to human health and the environment through the implementation of institutional controls such as deed restrictions, monitoring, and capping. Alternative S/W-3 includes implementation of deed restrictions to limit future site use and monitoring of storm water discharge to comply with regulations concerning land disposal facilities which have received industrial waste. Alternative S/W-3 also includes a shoreline protection component to protect shoreline areas from storm events. The main component of Alternative S/W-3 is the construction of a cap over the landfill area, as indicated in Figure 4-1. Generally, caps minimize direct exposures to surficial contaminants, provide some restriction of the infiltration of precipitation into underlying waste materials and minimize potential erosion of surficial contaminants. Three containment options considered for the Allen Harbor Landfill include a native soil cap, RCRA Subtitle C Hybrid Cap, and a RCRA Subtitle C Landfill Cap; these are discussed in more detail with respect to the evaluation criteria in Sections 4.2.7 to 4.2.12. The discussions presented in this section and Section 4.2.6 are intended to provide a general basis for comparison of this alternative with other alternatives.

An evaluation of Alternative S/W-3 with respect to federal and state chemical-specific, location-specific, and action-specific ARARs/TBCs is presented in Tables 4-4 through 4-6. Storm water discharge monitoring would be required under this alternative to meet ARARs/TBCs.

4.2.6 Alternative S/W-3 - Containment Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative S/W-3 provides protection of human health and the environment through the minimization of potential exposures to the site contaminants and by minimizing the potential migration of contaminants due to erosion. Alternative S/W-3 would result in some increased short-term risks during implementation but would be effective in the long-term. The capping options would comply with chemical-specific, action-specific and location-specific ARARs/TBCs.

Compliance with ARARs - By preventing exposures to PCBs and lead in site soils in the future, the capping options would meet chemical-specific ARARs/TBCs, as indicated in Table 4-4.

Cap construction activities at the site would be conducted in accordance with location-specific ARARs listed in Table 4-5. The capping options would comply with action-specific ARARs including federal and state ARARs applicable to storm water discharge and venting, and relevant and appropriate landfill closure requirements, as listed in Table 4-6.

Long-Term Effectiveness and Permanence - Alternative S/W-3 would reduce the potential risks associated with direct contact with site-related contaminants but some residual risk would remain since the source (the landfill) is not treated or removed. The containment options are expected to be relatively reliable in the long-term although periodic maintenance may be required. Ground water would still remain in contact with waste materials, mainly in the southern portion of the site. Since wastes would remain on-site above levels that allow for unlimited use and unrestricted exposure, a five-year review of Alternative S/W-3 would be required.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative S/W-3 provides no treatment or destruction of site contamination. Reductions in contaminant mobility due to erosion of surficial contaminants and/or due to infiltration of precipitation through the waste materials and leaching of contaminants to the ground water would be achieved to various degrees depending on the selected capping option.

Short-Term Effectiveness - Due to the site disturbance required to implement Alternative S/W-3, some increased short-term risks to workers could result. Erosion containment measures (e.g. silt fences) could be used to minimize environmental impacts resulting from implementation. Remedial action objectives associated with minimizing potential risk to human health associated with exposure to surface soil contaminants and minimizing potential environmental impacts by reducing off-site migration of surface soil contaminants would be met by this alternative. The implementation period of Alternative S/W-3 varies from one to two years, depending on the containment option.

Implementability - Implementation of this alternative would require a significant construction effort but could be achieved. Implementation of Alternative S/W-3 will depend on the availability of capping materials. Construction activities associated with shoreline protection may be difficult to implement. The containment features of this alternative could be impacted if implementation of future remedial actions was required.

Cost - The main costs associated with this alternative are those associated with construction and long-term maintenance of the various cap designs. Total present worth costs are estimated to range from $2,700,000 to $5,400,000, depending on the capping option selected, as detailed in Sections 4.2.8, 4.2.10 and 4.2.12.

4.2.7 Alternative S/W-3A - Native Soil Cap Containment Option Description

One containment option which could be implemented involves the construction of a native soil cap over the landfill area. The native soil cap would limit direct contact with contaminated soil and minimize runoff of contaminated soil. The native cap would support similar species of deep-rooted plants which currently exist at the site. For this evaluation, it has been assumed that the cap would consist of native soil five feet thick to allow for the re-establishment and support of existing vegetation. A typical section through the native soil cap is presented in Figure 3-2. A more detailed vegetative analyses could be required to determine the actual soil thickness necessary to support existing species. Alternative S/W-3A would include storm water discharge monitoring to comply with regulations associated with land disposal facilities which have received industrial wastes. No landfill gas controls are included in this alternative since the native soil cap would not provide an impermeable barrier to landfill gas migration. Alternative S/W-3A would have to be combined with a sediment containment alternative, as described in Section 4.6.5, to provide shoreline protection in case of storm events.

An evaluation of Alternative S/W-3A with respect to federal and state chemical-specific, location-specific, and action-specific ARARs/TBCs is presented in Tables 4-4 through 4-6.

4.2.8 Alternative S/W-3A - Native Soil Cap Containment Option Evaluation

Overall Protection of Human Health and the Environment - Alternative S/W-3A provides protection of human health and the environment through the minimization of potential exposures to the site contaminants and by minimizing the potential migration of contaminants due to erosion. The native soil cap would have a limited effect in terms of controlling leachate seeps.

The native soil cap would comply with chemical-specific, action-specific and location-specific ARARs/TBCs. Alternative S/W-3A would result in some increased short-term risks during implementation but would be effective in the long-term.

Compliance with ARARs - If combined with long-term management and institutional controls, the native soil cap would meet the definition of a RCRA hybrid cap in compliance with relevant and appropriate RCRA requirements (see Appendix A). By preventing exposures to contaminants in the future, Alternative S/W-3A would meet federal and state chemical-specific ARARs, as indicated in Table 4-4. The native soil cap would have to be constructed within the toeprint of the existing landfill in order to comply with location-specific ARARs/TBCs identified in Table 4-5. If cap construction cannot be limited to areas within the toeprint of the existing landfill, mitigation of any impacted wetlands may be required. Construction of the native soil cap will be conducted according to the pertinent action-specific ARARs/TBCs listed in Table 4-6.

Long-Term Effectiveness and Permanence - Some residual risk remains since the source (the landfill) is not treated or removed, but contained by the native soil cap. While the cap will provide more protection against infiltration than existing site conditions, it may not be reliable in eliminating leachate steeps. Ground water would still remain in contact with waste materials in the southern portion of the site, where wastes are present beneath the water table. With proper maintenance, a soil cap would offer reliable, long-term protection against the risks associated with direct contact with contaminants and surface migration of contaminants. Since wastes would remain on-site above levels that allow for unlimited use and unrestricted exposure, a five-year review of Alternative S/W-3A would be required.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative S/W-3A provides no treatment or destruction of site contamination. However, reductions in contaminant mobility associated with surficial erosion would be achieved through the construction of a soil cap.

Short-Term Effectiveness - Potential short-term risks associated with the implementation of Alternative S/W-3A include the possibility of exposures to contaminants during the construction of the native soil cap, although personnel protective equipment could be utilized to minimize these risks. Potential migration of contamination during construction due to run-off could be minimized through the use of drainage control systems. Off-site impacts of construction would be expected to be minimal. Remedial response objectives would be addressed by Alternative S/W-3A by limiting direct contact with contaminated soil and minimizing runoff of contaminated soil. The time frame required for this alternative to meet remedial response objectives is estimated to be approximately one year.

Implementability - Alternative S/W-3A would be relatively easy to implement. The construction of a soil cap employs commonly used and widely accepted construction equipment, materials, and techniques. Site preparation would entail clearing of site vegetation and regrading. Some movement and recompaction of existing waste materials could be required. Implementation of a soil cap should not pose a significant barrier to the implementation of other remedial actions.

Cost - The main costs associated with this alternative are those associated with construction and long-term maintenance of the native soil cap. The cost of implementation for Alternative S/W-3A is estimated to include $1,700,000 in direct capital costs, $240,000 in indirect capital costs and $20,000 in annual operation and maintenance costs ($300,000 net present value). The present worth value of this alternative, including contingency, is estimated at $2,700,000. A detailed cost estimate is presented in Appendix E.

4.2.9 Alternative S/W-3B - RCRA Subtitle C Hybrid Cap Containment Option Description

This alternative involves the capping of the Allen Harbor Landfill site with a RCRA Subtitle C hybrid cap designed in accordance with relevant and appropriate RCRA requirements. When RCRA Subtitle C closure requirements are relevant and appropriate but not applicable to a site, consideration of a hybrid closure is possible, as discussed in the ARARs discussion of Appendix A. If residual contamination which poses a direct contact threat but does not pose a ground water threat exists, a hybrid closure consisting of a cover, which may be permeable, to address the direct contact threat, limited long-term management and minimal ground water monitoring and institutional controls, as necessary, can be considered (USEPA, 1989c). Based on the leaching model presented in Section 3.2.4, leaching of contaminants from unsaturated subsurface materials is not a major concern at Site 09. However, discharge of contaminated ground water to the environment via leachate seeps could pose a direct pathway for contaminant discharge to the environment. Therefore, the cap proposed for the hybrid closure alternative provides protection against leachate seeps but does not include a double barrier system typical of most RCRA Subtitle C caps designed for sites where RCRA closure requirements are applicable.

An evaluation of Alternative S/W-3B with respect to federal and state chemical-specific, location-specific, and action-specific ARARs/TBCs is presented in Tables 4-4 through 4-6. The RCRA Subtitle C hybrid cap meets the requirements of a RIDEM solid waste capping requirements.

The RCRA Subtitle C hybrid cap proposed for the Allen Harbor Landfill site has been developed according to relevant and appropriate RCRA requirements and is described below (from visible top surface to top of waste) :

- Vegetative and protective layer - 24 inches of native soil, assumed to consist of 6 inches of topsoil, 18 inches of soil fill
- Geonet drainage layer
- Synthetic geomembrane
- 12" bedding layer

The final landfill surface would be constructed with a minimum five percent slope to prevent ponding on top of the cap and limit erosion. Side slopes would be constructed with a typical maximum 3:1 (33%) slope. The final slope design along the shoreline of Allen Harbor would be determined based on an evaluation of existing site conditions conducted during the final design process. Details associated with the proposed cap are provided in Figure 3-3.

The vegetative/protective layer, the surficial layer of the cap, provides stability and erosion control. It also provides protection for the drainage layer and for the synthetic liner. The RCRA hybrid cap's vegetative layer could only support relatively shallow-rooted species (e.g., grasses), but the presence of a meadow-type area could enhance the biodiversity of the Allen Harbor area. If necessary for frost protection, the thickness of the soil fill layer could be increased.

The drainage layer minimizes the time any infiltration contacts the geomembrane and thus reduces the potential for water to reach the underlying waste. Water that migrates through the vegetative/protective layer would drain laterally through the drainage layer due to the slope of the cap. The drainage layer can consist of a sand or granular material layer or a geosynthetic drainage layer (geonet). For this evaluation, the use of a geonet has been assumed. A geonet is a structure made of two sets of plastic strands arranged together to form a "net". The arrangement of these strands allows for fluids to be easily conveyed along the plane of the net. RIDEM solid waste landfill closure requirements require that the geonet have a hydraulic transmissivity equivalent to a 1-ft thick layer of sand having a minimum coefficient of permeability of 1×10^{-1} cm/sec. Filter fabric material could be used between the vegetative/protective layer and the geonet to prevent intrusion of soil into and subsequent clogging of the geonet.

The geomembrane lies beneath the drainage layer and provides an impermeable layer which prevents water from migrating deeper into the landfill. Water that reaches the geomembrane drains to the side of the cap due to the cap's slope and the presence of the drainage layer. RIDEM solid waste landfill closure regulations require the use of a geomembrane cover with a maximum coefficient of permeability of 1×10^{-12} cm/sec with a minimum thickness of 36 mils (or 60 mils for HDPE).

The bedding layer provides a bed upon which the geomembrane can be installed with minimal potential for puncturing of the geomembrane. The bedding layer consists of a 12-inch thick layer of soil located over the compacted waste and below the geomembrane.

Since the presence of the hybrid cap would decrease the vertical migration of landfill gas through the surface of the landfill, and could potentially result in an increase in lateral gas migration and pressure under the cap which could damage the integrity of the synthetic and other layers, an optional gas vent layer could be incorporated into the cap design. Field tests would need to be conducted during the design phase to determine if a landfill gas management system is required to protect the integrity of the cap. As determined to be necessary, the gas vent layer, vertical risers (pipe vents or gas vent wells) and/or horizontal venting pipes could be installed across the site and passive or active venting utilized to manage the release of landfill gases.

Slope protection and a reduction in the existing grade would be required along the perimeter of the final cover adjacent to Allen Harbor to prevent erosion from tidal action and storm surges or washout of waste materials. In accordance with the Clean Water Act Section 404, the slope protection features along Allen Harbor could not extend beyond the toeprint of the existing landfill. If during the design process it is determined that the cap cannot be constructed in accordance with this requirement, mitigation of any impacted wetlands may be required.

Adjacent to the remainder of the site's perimeter, storm water run-off control swales would be used, as necessary, to control run-on and run-off from the cap. The entire cap would be seeded and/or planted following installation to minimize erosion due to run-off.

4.2.10 Alternative S/W-3B - RCRA Subtitle C Hybrid Cap Containment Option Evaluation

Overall Protection of Human Health and the Environment - Alternative S/W-3B provides overall protection of human health and the environment through the minimization of potential exposures to the site contaminants and by minimizing the potential migration of contaminants due to erosion. The RCRA Subtitle C hybrid cap would provide additional protection by reducing leachate seeps from the side slopes of the landfill. The hybrid cap would comply with chemical-specific, action-specific and location-specific ARARs/TBCs. This alternative could result in some increased short-term risks during implementation but would be effective in the long-term.

Compliance with ARARs - By preventing exposures to contaminants in the future, Alternative S/W-3B would meet federal and state chemical-specific ARARs, as indicated in Table 4-4. The hybrid cap would have to be constructed within the toeprint of the existing landfill and minimize impacts to wetlands and/or coastal areas in order to comply with the location-specific ARARs/TBCs listed in Table 4-5. If cap construction cannot be limited to areas within the toeprint of the existing landfill, mitigation of any impacted wetlands will be required. Hybrid cap construction activities will be conducted according to action-specific ARARs/TBCs. If combined with long-term management and institutional controls, the RCRA Hybrid cap would meet relevant and appropriate RCRA requirements. In addition, ~~the hybrid cap would comply with RIDEM solid waste landfill closure requirements.~~

Long-Term Effectiveness and Permanence - Alternative S/W-3B would significantly reduce the potential risks associated with direct contact with site-related contamination but some residual risk would remain since the source (the landfill) is not treated or removed. The RCRA

Subtitle C hybrid cap would be effective in the long-term minimization of future leachate seeps. Ground water would still remain in contact with waste materials in the southern portion of the site. The long-term effectiveness of landfill caps can be impacted by differential settlements of the landfill contents, large gas pressures under the cap, or slope erosion. While the age of the landfill should result in minimal future settlement of the contents, the potential for settlement must be considered in the final cap design. Potential generation of landfill gas, which could impair the effectiveness of the cap, would require further investigation prior to design. With proper maintenance, a hybrid cap would offer reliable, long-term protection against direct contact with or surficial erosion of contaminants. Since wastes would remain on-site above levels that allow for unlimited use and unrestricted exposure, a five-year review of Alternative S/W-3B would be required.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative S/W-3B provides no treatment or destruction of site contamination. However, reductions in contaminant mobility due to erosion of surficial contaminants and due to infiltration of precipitation would be achieved through the construction of the hybrid cap.

Short-Term Effectiveness - Potential short-term risks associated with the implementation of Alternative S/W-3B include the possibility of exposures to contaminants during the construction of the RCRA Subtitle C hybrid cap, although personnel protective equipment could be utilized to minimize these risks. Potential migration of contamination during construction due to run-off would be minimized through the use of drainage control systems. Off-site impacts of construction would be expected to be minimal. The time frame required for this alternative to meet remedial response objectives is estimated to be approximately one to two years.

Implementability - Several factors affect the implementability of Alternative S/W-3B. Site preparation would entail clearing of site vegetation and regrading. Some movement and recompaction of existing waste materials could be required. The construction of the hybrid cap requires the use of a synthetic liner. Installation of a synthetic liner requires a specialty contractor to ensure proper installation. Special care is also required in the placement of the drainage and vegetative layers over the synthetic liner to ensure the membrane is not punctured. As mentioned previously, additional studies would be required during the design phase to determine if a landfill gas management system is required, and to properly design the cap along the shoreline to provide slope stability and protection against erosion or washout during storm events. Due to the existing steep slope along Allen Harbor and the potential slope stability problems associated with the interface between soil layers and smooth geomembrane materials, cap construction along Allen Harbor could be difficult. If the capping alternative were combined with the sheet piling alternative evaluated in Section 4.413, the sheet piling could provide shoreline protection and be tied into the hybrid cap. Overall, the RCRA Subtitle C hybrid cap should be implementable.

Cost - The main costs associated with this alternative are those associated with construction and long-term maintenance of the hybrid cap and shoreline protection. The cost of implementation for Alternative S/W-3B is estimated to include $2,400,000 in direct capital costs, $340,000 in indirect capital costs and $24,000 in annual operation and maintenance costs ($370,000 net present value). The present worth value of this alternative, including contingency, is estimated at ~~$3,800,000.~~ The total cost of Alternative S/W-3B not including the associated costs of stone revetment, is approximately $3,300,000. Detailed cost estimates are presented in Appendix E. If landfill gas treatment is required, additional costs could be incurred.

4.2.11 Alternative S/W-3C - RCRA Landfill Cap Containment Option Description

This alternative involves the capping of the Allen Harbor Landfill site with a RCRA Subtitle C Landfill cap, designed in strict compliance with RCRA landfill closure requirements. The cap would minimize direct exposures to surficial contaminants, minimize infiltration of precipitation into underlying waste materials and minimize potential erosion of surficial contaminants.

An evaluation of Alternative S/W-3C with respect to federal and state chemical-specific, location-specific, and action-specific ARARs/TBCs is presented in Tables 4-4 through 4-6.

The RCRA Subtitle C landfill cap proposed for the Allen Harbor Landfill site has been developed according to RCRA requirements and is described below (from visible top surface to top of waste):

- Vegetative and protective layer - 24 inches of native soil, assumed to consist of 6 inches of topsoil, 18 inches of soil fill
- Geonet drainage layer
- Synthetic geomembrane

- 24" barrier layer (low permeability clay soil)
- 12" bedding layer

Details associated with the proposed cap are provided in Figure 3-4. The main difference between this cap and the hybrid cap analyzed in Sections 4.2.9 and 4.2.10 is the double-barrier system formed by the presence of both a synthetic barrier and soil barrier. Since the other cap layers and general cap design parameters (e.g. slope) were previously described in Section 4.2.9, this discussion focuses on the double barrier system.

The double barrier system would consist of a combination of synthetic and low permeability soil layers to provide maximum protection against ground water infiltration. The synthetic geomembrane would overlay a 24-inch thick barrier layer of compacted clay. Should infiltration penetrate the geomembrane, the compacted clay would act as an added barrier to its downward migration.

As with Alternative S/W-3B, an optional gas vent layer could be incorporated into the cap design if determined to be necessary. Field tests would need to be conducted during the design phase to determine if a landfill gas management system is required to protect the integrity of the cap. As determined to be necessary, the gas vent layer, vertical risers (pipe vents or gas vent wells) and/or horizontal venting pipes could be installed across the site and passive or active venting utilized to manage the release of landfill gases.

Slope protection and a reduction in the existing grade would be required along the perimeter of the final cover adjacent to Allen Harbor to prevent erosion from tidal action and storm surges or washout of waste materials. In accordance with the Clean Water Act Section 404, the slope protection features along Allen Harbor could not extend beyond the toeprint of the existing landfill. If during the design process it is determined that the cap cannot be constructed in accordance with this requirement, mitigation of any impacted wetlands would be required.

Adjacent to the remainder of the site's perimeter, storm water run-off control swales would be used, as necessary, to control run-on and run-off from the cap. The entire cap would be seeded and/or planted following installation to minimize erosion due to run-off from the capped area.

4.2.12 Alternative S/W-3C - RCRA Landfill Cap Containment Option Evaluation

Overall Protection of Human Health and the Environment - The RCRA Subtitle C multi-layer cap would provide similar protection to human health and the environment as the hybrid cap (Alternative S/W-3B). The combined soil and synthetic barrier layers would provide a greater barrier to the infiltration of precipitation into the landfill, and therefore would reduce the volume of leachate produced. However, the modeling of leaching from unsaturated soils as described in Section 3.2.4, indicated that contaminant leaching is not expected to be a major concern. Therefore, the additional protection offered by the combined double-barrier layer is not expected to be significant. The alternative would meet chemical-specific, location-specific and action-specific ARARs. The cap design would exceed relevant and appropriate RCRA hazardous waste landfill closure requirements. Due to the multi-layer design, it would be effective in the long-term although increases in the short-term risks could be anticipated during construction.

Compliance with ARARs - Alternative S/W-3C prevents exposures to soil contaminants and thereby meets federal and state chemical-specific ARARs/TBCs, as listed in Table 4-4. The alternative would comply with location-specific ARARs, as listed in Table 4-5, and with action-specific ARARs, including federal and state ARARs applicable to storm water discharge monitoring and venting as listed in Table 4-6. Compliance with state and federal ARARs pertaining to hazardous waste landfill closure would be achieved under this alternative. Alternative S/W-3C would exceed relevant and appropriate RCRA requirements.

Long-Term Effectiveness and Permanence - Alternative S/W-3C would significantly reduce the potential risks associated with direct contact with site-related contamination but some residual risk would remain since the source (the landfill) is not treated or removed. While the RCRA Subtitle C multi-layer cap would be effective in virtually eliminating infiltration of precipitation, ground water would still remain in contact with waste materials in the southern portion of the site. It would also be effective in the long-term in reducing leachate seeps from the side slopes of the landfill. The long-term effectiveness of landfill caps can be impacted by differential settlements of the landfill contents, large gas pressures under the cap, or slope erosion. While the age of the landfill should result in minimal future settlement of the contents, the potential for settlement must be considered in the final cap design. Landfill gas generation, which could impair the effectiveness of the cap, would require further investigation prior to cap design and, if necessary, a landfill gas treatment system would be provided. With proper maintenance, a multi-layer cap would offer reliable, long-term protection from risk associated with direct contact with contaminants. Since wastes would remain on-site above levels that allow for unlimited use and unrestricted exposure, a five-year review of Alternative S/W-3C would be required.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative S/W-3C provides no treatment or destruction of site contamination. However, reductions in contaminant mobility due to erosion of surficial contaminants and due to the discharge of leachate seeps would be achieved through the construction of the multi-layer cap.

Short-Term Effectiveness - Potential short-term risks associated with the implementation of Alternative S/W-3C include the possibility of exposures to contaminants during the construction of the RCRA Subtitle C multi-layer cap, although personnel protective equipment could be utilized to minimize these risks. Potential migration of contamination during construction due to run-off would be minimized through the use of drainage control systems. Off-site impacts of construction would be expected to be minimal. The time frame required for this alternative to meet remedial response objectives is estimated to be approximately two years.

Implementability - Several factors affect the implementability of Alternative S/W-3C. Site preparation would entail clearing of site vegetation and regrading. Some movement and recompaction of existing waste materials could be required. The construction of the multi-layer cap requires the use of a soil barrier as well as a synthetic liner. Sufficient volumes of low permeability soil for the barrier layer may be difficult to obtain. Installation of a synthetic liner requires a specialty contractor to ensure proper installation. Special care is also required in the placement of cap layers over the synthetic liner to ensure the membrane is not punctured. As mentioned previously, additional studies would be required during the design phase to determine if a landfill gas management system is required, and to properly design the shoreline portion of the cap to provide slope stability and protection against erosion or washout during storm events. Due to the existing steep slope along Allen Harbor and the potential slope stability problems associated with the interface between soil layers and smooth geomembrane materials, cap construction along Allen Harbor could be difficult. If combined with the sheet piling alternative described in Section 4.4.13, the sheet piling could provide shoreline protection and be tied into the cap. Overall, the RCRA Subtitle C multi-layer cap should be implementable.

Cost - The main costs associated with this alternative are those associated with construction and long-term maintenance of the multi-layer cap. The cost of implementation for Alternative S/W-3C is estimated to include $3,600,000 in direct capital costs, $500,000 in indirect capital costs and $24,000 in annual operation and maintenance costs ($370,000 net present value). The present worth value of this alternative, including contingency, is estimated at $5,400,000. The total cost of Alternative S/W-3C not including the associated costs of stone revetment is approximately $4,800,000. Detailed cost estimates are presented in Appendix E. If landfill gas treatment is required, additional costs could be incurred.

4.3 Soil/Waste Alternatives Comparative Evaluation

A comparative analysis is conducted to evaluate the significant differences between the alternatives based on the threshold and balancing criteria. Tabular comparisons of the alternatives based on the seven evaluation criteria are presented in Tables 4-7 through 4-13, respectively.

4.3.1 Overall Protection of Human Health and the Environment

A comparative analysis of the remedial alternatives with respect to overall protection of human health and the environment is presented in Table 4-7.

Alternative S/W-3 provides the greatest degree of long-term protection of human health and the environment through the minimization of potential exposures to site contaminants and by minimizing the potential migration of contaminants due to erosion. Three options considered under the containment alternative (Alternative S/W-3) include a native soil cap (S/W-3A), a RCRA Subtitle C hybrid cap (S/W-3B), and a RCRA Subtitle C landfill cap (S/W-3C). While Option S/W-3C would provide the greatest barrier to the infiltration of precipitation into the landfill, due to the combined soil and synthetic barrier layers, the leaching model analysis described in Section 3.2.4 indicated that leaching from unsaturated subsurface materials may not be significant. Because both Options S/W-3B and S/W-3C would provide protection against leachate seeps from the side slopes of the landfill, they are considered to offer a similar degree of overall protection. Option S/W-3A may not be as effective in limiting leachate seeps, and therefore is considered to be slightly less protective than Options S/W-3B and S/W-3C. All three of the Alternative S/W-3 options would comply with chemical-specific, action-specific and location-specific ARARs/TBCs. Option S/W-3C would exceed relevant and appropriate requirements RCRA hazardous waste landfill closure requirements. All three options considered under Alternative S/W-3 would result in some increased short-term risks to workers during implementation. In addition, all of the options of Alternative S/W-3 would be effective in the long-term.

Alternative S/W-2 provides a limited degree of protection of human health by limiting potential exposures to site contaminants through site fencing and deed restrictions. Alternative S/W-2 provides no additional protection of the environment. Alternative S/W-2 does not comply with chemical-specific ARARs/TBCs. Alternative S/W-2 is effective in the short-term, but does not provide the long-term effectiveness offered by Alternative S/W-3.

The no action alternative is not considered to be protective of human health or the environment since it provides no reduction in potential risks or control of exposure pathways. It would not be effective in the long- or short-term and does not comply with chemical-specific ARARs.

4.3.2 <u>Compliance with ARARs</u>

A comparative analysis of the remedial alternatives with respect to their compliance with ARARs is presented in Table 4-8.

Alternative S/W-3 provides the best compliance with chemical-specific, location-specific, and action-specific ARARs/TBCs. By preventing exposures to PCBs and lead in soils in the future, Alternative S/W-3 would meet chemical-specific criteria. Implementation of construction activities would comply with location-specific criteria (i.e. wetland and coastal zone requirements). In addition, Alternative S/W-3 would comply with action-specific criteria applicable to storm water discharge, venting, and relevant and appropriate landfill closure requirements. The native soil cap option (S/W-3A) would meet the definition of a RCRA hybrid cap in compliance with relevant and appropriate RCRA requirements. The RCRA Subtitle C hybrid cap would comply with relevant and appropriate RCRA requirements as well as RIDEM solid waste landfill closure requirements. The RCRA Subtitle C landfill cap would meet state and federal action-specific ARARs pertaining to hazardous waste landfill closure. Option S/W-3C would exceed relevant and appropriate RCRA requirements.

Alternative S/W-2 provides some degree of compliance with state and federal ARARs. Alternative S/W-2 does not address PCBs or lead in site soils and therefore does not meet chemical-specific ARARs. Implementation of fencing would comply with wetland and coastal zone location-specific criteria. In addition, storm water discharge monitoring would be conducted in accordance with NPDES and RIPDES requirements.

Alternative S/W-1 does not address PCBs or lead in site soils and therefore does not meet chemical-specific ARARs. Alternative S/W-1 involves no actions which impact coastal or wetland areas and therefore, meets location-specific criteria. Since no actions are conducted under Alternative S/W-1, other than a five year review, action-specific ARARs/TBCs are not applicable.

4.3.3 Long-Term Effectiveness and Permanence

A comparative analysis of the remedial alternatives with respect to long-term effectiveness and permanence is presented in Table 4-9.

Alternative S/W-3 involves the placement of a cap over the landfill area and the associated long-term maintenance. Alternative S/W-3 provides a greater degree of long-term effectiveness and permanence than Alternatives S/W-2 and S/W-1 by reducing the potential risks associated with direct contact with site-related contaminants. For Alternative S/W-3, some residual risks would remain since the source (the landfill) is not treated or removed. The containment options are expected to be relatively reliable in the long-term although periodic maintenance may be required. Containment Option S/W-3A is effective in the long-term in limiting potential physical exposures to surficial contamination but is not as effective as Options S/W-3B and S/W-3C in limiting potential infiltration of precipitation or leachate seeps. However, Option S/W-3A could support existing vegetation, whereas Options S/W-3B and S/W-3C could support only shallow-rooted species.

Alternative S/W-2 relies on institutional controls to limit human exposures to site contamination. Alternative S/W-2 would require long-term maintenance of site fencing and deed restrictions to maintain its effectiveness. Due to its limited scope, it would not provide the same degree of long-term effectiveness, permanence or reliability as Alternative S/W- 3. Alternative S/W-1 would not be effective in the long-term since no controls would be implemented to limit potential exposures to site contamination. All of the alternatives would require a five-year review since wastes would remain on-site above levels that allow for unlimited use and unrestricted exposures.

4.3.4 Reduction of Toxicity, Mobility and Volume through Treatment

A comparative analysis of the remedial alternatives with respect to reductions of toxicity, mobility and volume thorough treatment is presented in Table 4-10.

Alternative S/W-3 provides no treatment or destruction of site contamination and therefore no associated reduction in contaminant toxicity, mobility, or volume. However, reductions in contaminant mobility due to erosion of surficial contaminants and/or infiltration of precipitation through the waste materials would be achieved to various degrees depending on the selected capping option. While all of the containment options would reduce contaminant mobility associated with surficial erosion, Options S/W-3B and S/W-3C would also reduce contaminant mobility associated with leachate seeps.

Alternative S/W-2 provides no treatment of site contamination and therefore no associated reduction in contaminant toxicity, mobility, or volume. However, site access restrictions would limit the potential human exposure pathways associated with current or future site use. Alternative S/W-1 provides no reduction in contaminant mobility, toxicity or volume except through natural degradation and attenuation.

4.3.5 Short-Term Effectiveness

A comparative analysis of the remedial alternatives with respect to short-term effectiveness is presented in Table 4-11.

Alternative S/W-3 would result in some increased short-term risks to workers due to site disturbance activities required to implement this alternative. However, personnel protective equipment would minimize these risks. Erosion containment measures could be used to minimize environmental impacts. Off-site impacts of construction activities would be expected to be minimal.. Remedial response objectives would be achieved for this alternative. The estimated implementation time frame for Options S/W-3A, S/W-3B, and S/W-3C would vary from one to two years.

Alternative S/W-2 would result in minimal short-term risks associated with fence construction. Alternative S/W-2 has a short implementation time frame. Remedial response objectives would not be achieved for Alternative S/W-2. Alternative S/W-1 requires no remedial activities to be conducted and therefore results in no increase in short-term risks. However, it does not achieve remedial response objectives.

4.3.6 Implementability

A comparative analysis of the remedial alternatives with respect to implementability is presented in Table 4-12.

Alternative S/W-1 requires no implementation other than a five year review. This alternative would not limit the implementation of other remedial actions. Alternative S/W-2 is easily implemented from a technical standpoint, involving the construction and maintenance of site fencing. The restriction of access due to site fencing would contradict the proposed recreational/conservational future site use specified under the Base Reuse Plan. Deed restrictions would have to be incorporated in the base closure property transfer process. Alternative S/W-2 would not limit the implementation of other remedial actions.

Alternative S/W-3 is the most difficult of the alternatives to implement with respect to constructability. Alternative S/W-3 requires clearing of existing site vegetation and regrading. Some movement and recompaction of existing waste materials would be required. The construction activities associated with shoreline protection may be difficult to implement. Containment features could be impacted if future remedial actions are required. Alternative S/W-3 could support future recreational or conservational site use as specified under the Base Reuse Plan.

The native soil cap option of Alternative S/W-3 would be more easily constructed than the RCRA Subtitle C hybrid cap and the RCRA Subtitle C landfill cap. Option S/W-3A employs commonly used equipment and construction materials and techniques. In addition, the construction of a native soil cap does not present a significant barrier to the implementation of other remedial actions. The implementation of the RCRA Subtitle C hybrid cap and the RCRA Subtitle C landfill cap would be more difficult to implement than Option S/W-3A, because these caps require special equipment and materials for geomembrane installation and extra care in placement of overlying cap materials to prevent puncture of the geomembrane. In addition, sufficient volumes of low permeability material for the barrier layer of the RCRA Subtitle C landfill cap may difficult to locate. Cap construction may be difficult for Options S/W-3B and S/W-3C, due to the existing steep slope along Allen Harbor and the potential slope stability problems associated with the interface between soil layers and smooth membrane materials. Options S/W-3B and S/W-3C could be combined with a stone revetment or sheet piling to provide shoreline protection. The presence of both of these caps could complicate implementation of other remedial actions.

4.3.7 Cost

A comparative analysis of the remedial alternatives with respect to cost is presented in Table 4-13. The costs of the alternatives increase with the increasing sophistication of the remedial action from the no action alternative (S/W-1) to the containment alternative (S/W-3) (from nominal cost to $5,400,000). The native soil cap option, which does not include a stone revetment, is considerably less expensive to implement ($2,700,000) than the comparable RCRA Subtitle C hybrid cap without stone revetment option ($3,300,000). In addition, the costs associated with the implementation of the RCRA Subtitle C hybrid cap ($3,800,000) are significantly less than those associated with the implementation of the RCRA Subtitle C landfill cap ($5,400,000).

4.4 Ground Water/Leachate Alternative Individual Descriptions and Evaluations

Four ground water/leachate remedial alternatives were developed, as described below.

4.4.1 Alternative GW-1 - No Action Alternative Description

The NCP requires consideration of the no-action alternative; at a minimum it provides a baseline for comparison with other alternatives. This alternative would involve no remedial response activities with respect to ground water or leachate at Allen Harbor Landfill. No removal or treatment of contaminated ground water would be conducted and no minimization of potential environmental risks associated with discharge of ground water contaminants to Allen Harbor or wetland areas would be achieved. Because remaining contamination would not allow for unlimited future use of the site, a five-year review of the no action decision would be required.

An evaluation of the no action alternative with respect to federal and state chemical-specific and location-specific ARARs/TBCs is presented in Tables 4-14 and 4-15, respectively. Since the alternative involves no actions, no action-specific ARARs/TBCs were identified for this alternative.

4.4.2 Alternative GW-1 - No Action Alternative Evaluation

Overall Protection of Human Health and the Environment - Because no direct association between ground water quality and impacts to the environment has been clearly defined, the no action alternative could be considered to be protective of the environment. It does not limit future use of the site, and therefore does not limit the potential for future exposures due to changes in site use (e.g., installation of a well on-site). This alternative's long-term effectiveness and compliance with ARARs would be dependent upon development of site-specific remediation criteria as well as a continued lack of identification of impacts to the environment in the future. This alternative does not include any long-term monitoring of the environment and therefore provides no means of identifying potential environmental impacts, should they occur in the future. Implementation of this alternative results in no short-term impacts to the site.

Compliance with ARARs - An evaluation of the no action alternative's compliance with chemical-specific ARARs and TBCs is presented in Table 4-14. Determination of compliance with chemical-specific ARARs is dependent on the development of site-specific remediation levels. While ground water and leachate contaminant levels exceed Ambient Water Quality Criteria, modification of these criteria based on the relative lack of environmental impacts currently identified as being associated with ground water contamination is appropriate prior to their application as ground water ARARs. Since Alternative GW-1 involves no actions which could impact areas covered by location-specific ARARs (see Table 4-15), it meets location-specific ARARs. Due to the lack of actions associated with this alternative, no action-specific ARARs were identified.

Long-Term Effectiveness and Permanence - The no action alternative offers no long-term effectiveness or permanence in addressing potential ground water contaminant migration from the site. Potential impacts to the environment could result, and no controls would be provided to identify these impacts or limit exposures. Due to the residual risk which would be associated with the no action alternative, a five-year review of the no action decision would be required under the NCP.

Reduction of Toxicity, Mobility, or Volume through Treatment - The no action alternative does not include any treatment methods other than naturally occurring degradation or attenuation processes. Therefore, the alternative offers no significant reductions in the toxicity, mobility, or volume of ground water contamination through treatment.

Short-Term Effectiveness - The no action alternative does not present any increased short-term risks due to the lack of activities associated with its implementation. The five-year review would provide the only means of ensuring continued compliance with remedial action objectives.

Implementability - The no action alternative would require no implementation other than a five-year review of the no action decision. Its implementation would not limit the future implementation of additional remedial actions.

Cost - The cost associated with the no action alternative would be the cost associated with the five-year review.

4.4.3 Alternative GW-2 - Limited Action Alternative Description

Alternative GW-2 was developed as a limited action option which provides no active ground water remediation but limits potential risks to human health and the environment through the implementation of institutional controls. Such controls could include implementation of a long-term monitoring program to monitor potential ground water contaminant migration and/or implementation of deed restrictions to limit future ground water use on site. While ground water at the site is classified as GB and is expected to have no value as a potable water source due to brackish qualities, there is no regulatory mechanism which limits the potential installation of a well at Site 09. Therefore, deed restrictions may be appropriate. The two institutional control options are discussed in more detail in Sections 4.4.5 and 4.4.7, respectively. The description presented in this section and the evaluation presented in Section 4.4.4 are intended to provide a general basis for comparison of this alternative with other alternatives.

An evaluation of Alternative GW-2 with respect to federal and state chemical-specific, location-specific and action-specific ARARs/TBCs is presented in Tables 4-14 through 4-16.

4.4.4 Alternative GW-2 - Limited Action Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-2 provides protection of human health and the environment by providing a mechanism for monitoring potential contaminant migration from the site, and thereby evaluating potential environmental risks associated with any identified contaminant migration, and/or by limiting future site use which could protect potential human exposures to the ground water contaminants.

Currently, no direct relationship between contaminated ground water discharge and minor exceedances of ambient water quality criteria and potential environmental risks associated with sediment quality in Allen Harbor Watershed has been identified. Unless such a relationship is established and a definite risk or ARAR exceedance identified to be associated with this relationship, limited action with respect to ground water is considered to be protective of the environment. If degradation of wetlands or waters was determined to be attributable to contaminated ground water migration, location-specific ARARs could be violated. The limited action alternative is effective in the short-term and would be effective in the long-term provided no degradation of surface water or sediment quality attributable to contaminated ground water migration is identified.

Compliance with ARARs - An evaluation of the limited action alternative's compliance with chemical-specific ARARs and TBCs is presented in Table 4-14. As with Alternative GW-1, determination of compliance with chemical-specific ARARs is dependent on the development of site-specific remediation levels. While ground water and leachate contaminant levels exceed Ambient Water Quality Criteria, modification of these criteria based on the relative lack of environmental impacts currently identified as being associated with ground water contamination is appropriate prior to their application as ground water ARARs. Since Alternative GW-2 involves no actions which could impact areas covered by location-specific ARARs (see Table

4-15), it meets location-specific ARARs. However, if degradation of wetlands or waters was determined to be attributable to contaminated ground water migration, location-specific ARARs could be violated. Any long-term monitoring conducted under this alternative would be conducted in accordance with the applicable action-specific ARARs listed in Table 4-16.

Long-Term Effectiveness and Permanence - Alternative GW-2 relies on the use of institutional controls to identify changing site conditions which may present increased risks to the environment. Since contamination would remain on-site above levels that allow for unlimited use and unrestricted exposure, a five-year review of Alternative GW-2 would be required.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative GW-2 provides no treatment of contaminated ground water or leachate and therefore no reduction in contaminant toxicity, mobility or volume.

Short-Term Effectiveness - Alternative GW-2 would be relatively effective in the short-term, due to the lack of activities associated with its implementation and therefore the lack of short-term risks which would result from implementation. Long-term monitoring would ensure that remedial action objectives continue to be achieved.

Implementability - Implementation of an alternative involving institutional controls such as a monitoring program or deed restrictions would generally be easy. Deed restrictions would have to be incorporated into the property transfer process following base closure. Implementation of Alternative GW-2 would not be expected to limit the implementation of future remedial actions.

Cost - Costs associated with the implementation of Alternative GW-2 would be those associated with the implementation of a monitoring program or establishment of deed restrictions. Based on the cost estimates developed for the options undergoing consideration, as described in Sections 4.4.6 and 4.4.8, the present worth value cost of implementation for Alternative GW-2 is estimated to be approximately $1,800,000, based on a thirty-year monitoring period.

4.4.5 Alternative GW-2A - Long-Term Monitoring Option Description

One institutional control option which could be implemented under the Limited Action remedial alternative involves the institution of a long-term ground water monitoring program to evaluate changes in ground water quality. This option is assumed to consist of the long-term monitoring of existing monitoring wells. Also included in this option is long-term monitoring of surface water and sediment quality in the vicinity of Site 09 to identify any changes in quality which may be attributable to contaminated ground water discharge.

For the purposes of cost estimation it has been assumed that the monitoring well network would consist of the existing eleven shallow and eight deep wells located at the site. The proposed wells to be included in the monitoring network are indicated in Figure 4-5. It is also assumed that eight surface water and eight sediment samples would also be collected. The exact number of samples and sample locations would be determined during the remedial design phase. Samples would be collected annually, with the samples analyzed for full TCL/TAL parameters. A 30-year monitoring period is assumed.

4.4.6 Alternative GW-2A - Long-Term Monitoring Option Evaluation

Overall Protection of Human Health and the Environment - The institution of a long-term ground water, surface water and sediment monitoring program would not provide overall protection of human health and the environment on its own, but it would provide a means of evaluating changes to ground water, surface water and sediment quality. Potential exposures associated with future construction of an on-site well or the presence of leachate seeps would not be addressed by this option. The monitoring program would comply with location- and action-specific ARARs. It would be effective in the long-term as well as in the short-term.

Compliance with ARARs - An evaluation of the long-term monitoring option of the limited action alternative's compliance with chemical-specific ARARs and TBCs is presented in Table 4-14. As with Alternative GW-1, determination of compliance with chemical-specific ARARs is dependent on the development of site-specific remediation levels. While ground water and leachate contaminant levels exceed Ambient Water Quality Criteria, modification of these criteria based on the relative lack of environmental impacts currently identified as being associated with ground water contamination is appropriate prior to their application as ground water ARARs. Since Alternative GW-2A involves no actions which could impact areas covered by location-specific ARARs (see Table 4-15), it meets location-specific ARARs. However, if degradation of wetlands or waters was determined to be attributable to contaminated ground water migration, location-specific ARARs could be violated. Long-term monitoring would be conducted in accordance with the applicable federal and state monitoring requirements listed in Table 4-16.

Long-Term Effectiveness and Permanence - The monitoring program would provide a reasonable means of monitoring potential changes in ground water, surface water and sediment quality. If monitoring indicated that waters or wetlands were being degraded by ground water discharge, additional remedial measures could be implemented. Because hazardous substances would remaining at the site above levels that allow for unlimited use and unrestricted exposure, a five-year review would be required to confirm the continued protectiveness of the alternative.

Reduction of Toxicity, Mobility or Volume Through Treatment - Alternative GW-2A provides no treatment nor associated reduction in contaminant toxicity, mobility or volume.

Short-Term Effectiveness - Implementation of the monitoring program would have minimal short-term adverse impacts based on the use of existing wells for ground water monitoring purposes. Remedial action objectives would be achieved by providing a means of monitoring potential changes to ground water, surface water and sediment quality and potential associated impacts to the surrounding environment. This alternative could be implemented immediately.

Implementability - The technical feasibility of ground water monitoring is good, based on the use of existing monitoring wells. Surface water and sediment monitoring is also technically feasible. The monitoring program would monitor exposure pathways and allow for the implementation of future remedial actions if discharge of ground water to the environment was determined to be associated with potential environmental risks. Implementation of additional remedial actions in the future would not be limited by the implementation of the monitoring program.

Cost - The major costs associated with the monitoring option include the long-term monitoring costs. The overall cost includes $100,000 in annual operation and maintenance costs ($1,500,000 net present value). The present worth value of this alternative, including contingency, is estimated at $1,800,000. A detailed cost estimate is presented in Appendix E.

4.4.7 Alternative GW-2B - Deed Restrictions Option Description

A second institutional control option which could be implemented under the Limited Action remedial alternative involves the use of deed restrictions to limit future development of the site and thereby limit potential future human exposures to contaminated ground water. While ground water is expected to be too brackish to use as a source of potable water, there are no regulations which prohibit or control the installation of an on-site well.

4.4.8 Alternative GW-2B - Deed Restrictions Option Evaluation

Overall Protection to Human Health and the Environment - Implementation of the deed restriction option would limit potential future human exposures to contaminated ground water which could occur should a well be installed on site. It would not protect against potential exposures to leachate seeps unless future site use was restricted. Since this alternative option does not address potential contaminated ground water migration, it would not monitor or protect against ground water migration or potential resultant impacts to the environment.

Compliance with ARARs - Determination of compliance with chemical-specific ARARs is dependent on the development of site-specific remediation levels. While ground water and leachate contaminant levels exceed Ambient Water Quality Criteria, modification of these criteria based on the relative lack of environmental impacts currently identified as being associated with ground water contamination is appropriate prior to their application as ground water ARARs. This alternative complies with location-specific ARARs, as indicated in Table 4-15. No action-specific ARARs were identified as being applicable to this alternative option.

Long-Term Effectiveness and Permanence - Provided deed restrictions are enforced, they can be effective in minimizing the long-term risks associated with the potential construction and use of an on-site well. Since contaminants will remain on site at levels which do not allow for unlimited use and unrestricted exposure, a five-year review of Alternative GW-2B would be required.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative GW-2B provides no treatment nor associated reduction in contaminant toxicity, mobility or volume.

Short-Term Effectiveness - Since implementation of deed restrictions is an administrative effort, no short-term risks would result from implementation of this option. This option would meet remedial response objectives related to minimizing potential human exposures to contaminated ground water due to on-site well installation.

Implementability - Deed restrictions would have to be implemented as part of the base closure property transfer process. Deed restrictions limiting future installation of on-site wells would not be expected to prevent future recreational/conservational use of the site. Implementation of this alternative would not limit the implementation of future remedial actions.

Cost - The costs associated with implementation of deed restrictions would primarily be limited to legal costs and could be incorporated into the base closure property transfer process. Therefore, no separate cost estimate was developed for this alternative.

4.4.9 Alternative GW-3 - Containment Alternative Description

Alternative GW-3 was developed as a containment option which provides no active remediation but limits potential risks to human health and the environment through the implementation of containment measures such as the construction of a cap to minimize leachate seeps and/or implementation of a vertical barrier such as sheet piling to limit ground water migration from the landfill area. These two containment control options are discussed in more detail in Sections 4.4.11 and 4.4.12, respectively. The descriptions provided in this section and Section 4.4.10 are intended to provide a general basis for comparison of this alternative with other alternatives.

An evaluation of Alternative GW-3 with respect to federal and state chemical-specific, location-specific and action-specific ARARs/TBCs is presented in Tables 4-17 through 4-19.

4.4.10 Alternative GW-3 - Containment Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-3 provides protection of human health and the environment by providing a means of limiting the migration of contaminated ground water from the landfill area. By limiting the potential for leachate seeps to discharge to surface water and/or the potential for discharge of contaminated ground water to surface water bodies, potential environmental impacts associated with those discharges would also be minimized. While no direct link between contaminated ground water discharge and minor exceedances of ambient water quality criteria or sediment quality impacts in the Allen

Harbor Watershed has been identified, additional protection would be provided against any impacts in the future by providing a means of containing ground water.

The alternative could result in some increased short-term risks during implementation due to disruption of the landfill area. An impermeable cap would be effective in the long-term in minimizing leachate seeps; a vertical barrier would also be expected to be effective in the long-term, although the quality of construction and its resistance to chemical corrosion would impact its overall effectiveness.

<u>Compliance with ARARs</u> - Determination of compliance with chemical-specific ARARs is dependent on the development of site-specific remediation levels. While ground water and leachate contaminant levels exceed Ambient Water Quality Criteria, modification of these criteria based on the relative lack of environmental impacts currently identified as being associated with ground water contamination is appropriate prior to their application as ground water ARARs. The containment options included in this alternative would be constructed in compliance with location-specific ARARs, as listed in Table 4-18. If construction of the containment features cannot be limited to within the existing toeprint of the landfill, wetlands mitigation measures may be required. Action-specific ARARs for each of the containment options would also be met. Action-specific ARARs are discussed in more detail in the following containment option evaluations (see Sections 4.4.12 and 4.4.14).

<u>Long-Term Effectiveness and Permanence</u> - Alternative GW-3 utilizes containment features to minimize any future releases of contaminated ground water which could impact the surrounding environment. The containment features are expected to be relatively reliable in the long-term although periodic maintenance may be required. Since contamination would remain on-site above levels that allow for unlimited use and unrestricted exposure, a five-year review of Alternative GW-3 would be required.

<u>Reduction in Toxicity, Mobility, or Volume through Treatment</u> - Alternative GW-3 provides no treatment of contaminated ground water or leachate although it does result in a reduction in contaminant mobility through its containment features.

<u>Short-Term Effectiveness</u> - Due to the site disturbance required to implement Alternative GW-3, some increased short-term risks could result during construction although personnel protective equipment could be utilized to minimize these risks. Remedial action objectives

associated with minimizing potential impacts to the environment due to ground water migration would be met by this alternative. The estimated time frame for implementation would be one to two years.

Implementability - Implementation of this alternative would require a significant construction effort but could be achieved. The containment features of this alternative could be impacted if implementation of future remedial actions was required.

Cost - Costs associated with the implementation of Alternative GW-3 would be those associated with the construction of a cap or a vertical barrier system. As discussed in Sections 4.4.11 through 4.4.14, providing a vertical barrier to ground water migration would be most effective if combined with an impermeable cap. Therefore, the total cost of this alternative, based on implementation of Option GW-3A alone or a combination of Options GW-3A and GW-3B, is estimated to range from a present worth value of $3,300,000 to $10,900,000.

4.4.11 Alternative GW-3A - Capping Containment Option Description

One containment option which could be implemented involves the construction of an impermeable cap over the landfill area. The cap would remove infiltration from acting as a source of leachate production as well as provide a barrier to leachate seeps which can discharge from the sideslopes of the landfill. Two impermeable capping options, a RCRA hybrid cap and a RCRA landfill cap, were evaluated in detail in Sections 4.2.9 through 4.2.12. Therefore, a detailed description of these options will not be repeated here. This discussion will focus on the evaluation of the effects of an impermeable landfill cap on potential ground water migration.

4.4.12 Alternative GW-3A - Capping Containment Option Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-3A provides protection of human health and the environment by providing a means of limiting the potential for leachate seeps to discharge to surface water; any potential environmental impacts associated with those discharges would also be minimized.

While ground water discharge has not been definitely tied to minor exceedances of ambient water quality criteria, the removal of leachate seeps as a potential source of surface water degradation would provide additional protection against future environmental impacts.

The alternative could result in some increased short-term risks during implementation but would be effective in the long-term.

Compliance with ARARs - Determination of compliance with chemical-specific ARARs is dependent on the development of site-specific remediation levels. While ground water and leachate contaminant levels exceed Ambient Water Quality Criteria, modification of these criteria based on the relative lack of environmental impacts currently identified as being associated with ground water contamination is appropriate prior to their application as ground water ARARs. Cap construction would comply with location-specific ARARs, as indicated in Table 4-18. If cap construction could not be conducted within the toeprint of the existing landfill, mitigation of any impacted wetlands may be required. Storm water discharge monitoring and landfill gas venting, if required, would be conducted in accordance with federal and state requirements, as noted in Table 4-19. Cap design would also comply with relevant and appropriate landfill closure requirements, as indicated in Table 4-19.

Long-Term Effectiveness and Permanence - An impermeable cap would be reliable in the long-term, although periodic maintenance may be required. While cap construction would remove the migration pathway for leachate seeps, it would not reduce the potential migration of contaminated ground water. Since contamination would remain on-site above levels that allow for unlimited use and unrestricted exposure, a five-year review of Alternative GW-3A would be required.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative GW-3A provides no treatment of contaminated ground water or leachate although it does result in a reduction in the mobility of leachate seeps.

Short-Term Effectiveness - Due to the site disturbance required to implement Alternative GW-3A, some increased short-term risks to construction workers could result. The use of personnel protective equipment could minimize these risks. No significant off-site impacts would be expected as a result of cap construction. Remedial action objectives associated with minimizing potential impacts to the environment due to ground water migration would be addressed in the long-term by this alternative through the discontinuation of potential leachate seepage leachate from the landfill surface.

Implementability - Implementation of this alternative would require a significant construction effort but could be achieved. Construction of the cap along the shoreline of Allen Harbor would require the implementation of slope protection features to protect the slope against the effects of storms and waves, as discussed in Sections 4.2.9 through 4.2.12. The containment features of this alternative could be impacted if implementation of a future remedial action was required.

Cost - Costs associated with the implementation of Alternative GW-3A would be those associated with the construction of the cap. The cost of Alternative GW-3A would depend on the selected cap design. As discussed in Sections 4.2.10 and 4.2.12, the cost of cap construction is estimated to range from a present worth value of $3,300,000 to $5,400,000, assuming a 30-year period for the storm water discharge monitoring.

4.4.13 Alternative GW-3B - Sheet Piling Containment Option Description

A second containment option which could be implemented involves the installation of sheet piling around the perimeter of the landfill to provide a vertical barrier to ground water migration. Since implementation of this option alone could result in a bathtub effect in which ground water could not move laterally in or out of the landfill area but infiltration of precipitation would continue to "fill" the landfill, this option would have to be combined with Alternative GW-3A to be effective.

The sheet piling would be installed around the perimeter of the landfill, providing a barrier to the lateral movement of ground water into and out of the landfill area. The perimeter length of the landfill is estimated to be approximately 3,700 feet. The seismic refraction survey conducted at Site 09 indicated that the depth to competent bedrock varies from approximately 25 to 81 feet below the surface. The depth of the installation of the piling would be determined on the basis of additional site studies and/or ground water modeling. For the purposes of this assessment, it is assumed that it will be installed to the bedrock surface.

Sheet piling is typically made of steel and can be coated or galvanized or provided with cathodic protection to protect against corrosive environments or chemical attack. The piles are constructed with edge interlocks. Typically the pilings are assembled at the edge interlocks prior to being driven into the ground. They are driven a few feet at a time using a drop hammer or vibratory hammer. Upon installation, the edge interlocks are initially relatively permeable; however, with the passage of time, fine soil particles are washed into the seams and the permeability is reduced. Along the shoreline of the site, the sheet piling would be designed to meet wave forces as well as earth pressures and hydrostatic and seep forces.

Also included in this alternative is the installation of observation wells to monitor ground water levels within and outside of the sheet piling. Long-term monitoring of ground water levels would provide a means of evaluating the effectiveness of the sheet piling in containing ground water within the landfill area.

4.4.14 Alternative GW-3B - Sheet Piling Containment Option Evaluation

Overall Protection to Human Health and the Environment - Placement of a vertical sheet piling barrier around the landfill would reduce the potential for ground water migration into and out of the landfill area. It would also provide an effective barrier to leachate seeps along the shoreline of the site. When combined with an impermeable cap, this alternative option would be successful in providing containment of contaminated ground water within the landfill area. Construction would be required to comply with pertinent location-specific and action-specific ARARs. Slight increases in short-term risks would occur during implementation. This alternative would be expected to be protective in the long-term, although the design life of sheet piling is limited to approximately 40 years.

Compliance with ARARs - Determination of compliance with chemical-specific ARARs is dependent on the development of site-specific remediation levels. While ground water and leachate contaminant levels exceed Ambient Water Quality Criteria, modification of these criteria based on the relative lack of environmental impacts currently identified as being associated with ground water contamination is appropriate prior to their application as ground water ARARs. Sheet piling construction would have to comply with the location-specific ARARs listed in Table 4-18. If construction could not be limited to within the toeprint of the existing landfill, wetlands mitigation could be required. Construction activities would also be required to be protective of potential migratory bird nesting areas, as indicated in Table 4-19.

Long-Term Effectiveness and Permanence - Sheet piling walls can have a performance life of up to 40 years, depending on site-specific conditions and the use of special coatings

(USEPA, 1985). Water levels would require monitoring within the landfill area to identify any build-up of water within the containment boundaries. Monitoring would also be conducted outside of the barrier to verify its effectiveness in containing the contaminated ground water. Along the shoreline, visual inspections could be conducted. Since contaminants would remain on-site at levels which do not allow for unlimited use and unrestricted exposure, a five-year review of Alternative GW-3B would be required.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative GW-3B provides no treatment of ground water contaminants but does provide a reduction in the potential mobility of the ground water. Since sediment contamination was identified at the toe of the landfill face, the sheet piling (depending on its exact location relative to the sediment sampling location) might also provide containment of contaminated sediments.

Short-Term Effectiveness - Implementation of a barrier wall would be expected to result in a minimal increase in short-term risks during construction. No increased off-site risks would be expected. Installation could occur within a relatively short time frame. This option would meet remedial response objectives related to minimizing potential contaminated ground water migration.

Implementability - While installation of sheet piling can be adversely affected by the presence of subsurface cobbles or boulders, subsurface conditions at Site 09 are not expected to pose a significant barrier to implementation. The presence of a vertical barrier would enhance the effectiveness of any active ground water extraction/treatment system, should one be implemented, and its presence would have to be considered in the implementation of any other remedial actions.

Cost - The costs associated with implementation of a sheet piling vertical barrier would consist of $3,700,000 in direct capital costs, $740,000 in indirect capital costs, $20,000 in annual operation and maintenance costs ($310,000 net present value). The present worth value of this alternative, including contingency, is estimated at $5,700,000. A detailed cost estimate is presented in Appendix E.

4.4.15 Alternative GW-4 - Extraction/Treatment/Discharge Alternative Description

Alternative GW-4 consists of active remediation of the ground water to reduce potential impacts on the surrounding environment. The alternative could provide hydraulic control of the contaminated ground water, thereby reducing any potential off-site migration. If combined with containment, the ground water table within the landfill area could be lowered, reducing the volume of waste in contact with the water table and thereby reducing the potential for continued leaching of contaminants to the ground water. However, upon discontinuation of remediation system operation, maintenance of a reduction in the water level would be dependent upon the presence (or lack thereof) and effectiveness of other containment features such as an impermeable cap or vertical barrier system. Even if such features are present, resaturation of waste materials and leaching of contamination could re-occur.

The extraction/treatment/discharge alternative would consist of separate options which would be combined to form a complete alternative. These options are described in detail in Sections 4.4.17 through 4.4.28. This discussion and the evaluation presented in Section 4.4.18 focuses on the extraction/treatment/discharge alternative in general terms, and will provide a basis for alternative comparisons.

The main contaminants of concern with respect to potential ground water migration, based on a comparison of ground water to Ambient Water Quality Criteria (AWQC - see Table 3-2), include chlorinated volatile organics and inorganics. PCBs were detected in one Phase I test pit water sample at a level exceeding AWQC but were not detected in monitoring well samples. Phase I leachate seep samples also contained pentachlorophenol (in one of four samples) and PCBs (in two of four samples) at levels exceeding AWQC.

4.4.16 Alternative GW-4 - Extraction/Treatment/Discharge Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-4 would provide active treatment of ground water at Site 09 and therefore, would provide a greater reduction in potential increases in future risks to human health and the environment which could be associated with contaminated ground water migration. Its long-term effectiveness would be good as long as the treatment system was operational but if treatment was discontinued, contamination could again leach from the waste materials into the ground water and potentially migrate off-site. It would be effective in the short-term. Due to the continued presence of waste materials, maintenance of cleanup levels achieved during operation of the treatment system would not be guaranteed once treatment is discontinued. The extraction/treatment/discharge options would be designed to comply with location-specific and action-specific ARARs/TBCs.

Compliance with ARARs - Determination of compliance with chemical-specific ARARs is dependent on the development of site-specific remediation levels. While ground water and leachate contaminant levels exceed AWQC, modification of these criteria based on the relative lack of environmental impacts currently identified as being associated with ground water contamination is appropriate prior to their application as ground water ARARs. The ground water treatment technologies evaluated within this alternative have been selected to provide remediation of ground water contaminants detected at levels exceeding AWQC. However, long-term compliance with AWQC following discontinuation of pump and treat would not be guaranteed since the in-place waste materials could continue to leach contaminants to the ground water. This alternative would meet those chemical-specific ARARs which would be applicable to the remedial actions employed (e.g., if wastes are generated as a by-product of a treatment process, a hazardous waste determination will be conducted and the maximum concentrations established under 40 CFR 261.24 Toxicity Characteristic will be applied to determined if the waste is hazardous based on the toxicity characteristic). Alternative GW-4 would also be designed to comply with location- and action-specific ARARs and TBCs, as defined in Tables 4-21 and 4-22.

Long-Term Effectiveness and Permanence - Ground water treatment would be effective in preventing contaminated ground water migration during operation but would not necessarily be effective in a permanent sense if ground water treatment is discontinued at some point in the future. Long-term ground water monitoring would be required to evaluate the effectiveness of the alternative after operations cease. Since contaminants would remain on-site at levels which do not allow for unlimited use and unrestricted exposure, a five-year review of Alternative GW-4 would be required.

Reduction of Toxicity, Mobility or Volume Through Treatment - Alternative GW-4 would utilize treatment to reduce the toxicity and mobility of existing contaminated ground water. However, since the source of contamination is not being treated, the risk of recontamination exists.

Short-Term Effectiveness - No significant risks to on-site workers or off-site risks are anticipated as a result of implementation of this alternative. The degree of short-term risk would be dependent upon the individual alternative options employed. Remedial response objectives would be achieved during operation of the treatment system but may not be maintained if treatment is discontinued.

Implementability - Implementation of a ground water extraction, treatment and discharge system would be relatively easy, with the possible exception of the discharge component. The technical implementability would be dependent upon the individual alternative options selected, with some treatment technologies more easily implemented than others. Services and materials should be readily available for the implementation of all options.

Cost - The cost of this alternative is dependent on the operational period as well as the individual options utilized in the final alternative. Based on the individual option evaluations presented in the following sections, the total cost of Alternative GW-4 is estimated to range from \$2,400,000 to \$13,000,000.

4.4.17 Alternative GW-4A - Ground Water Extraction Option Description

Initial modeling was conducted to evaluate a potential ground water extraction system design, as described in detail in Appendix F. The computer ground water flow model MODFLOW was used to simulate the shallow and deep flow regimes at the site, and to arrive at an optimal configuration of shallow and deep extraction wells. The shallow aquifer was assumed to be comprised of the surficial fill layer and the sand and silt layer underlying the fill, and the deep aquifer was assumed to be the basal 40-foot silt layer directly overlying the bedrock at the site. After the initial model calibration and the performance of a cap-only simulation, three extraction scenarios were simulated:

- Impermeable cap over landfill, shallow and deep aquifer ground water extraction
- Impermeable cap over landfill, sheet piling installed along Sanford Road to top of silt layer, shallow and deep aquifer ground water extraction

- Impermeable cap over landfill, sheet piling installed surrounding entire landfill to top of silt layer, shallow aquifer dewatering and deep aquifer ground water extraction.

The extraction simulations indicated that, due to the low permeability of both the shallow and deep aquifers, thirteen shallow extraction wells pumping from 0.25 gallons per minute (gpm) to 2.75 gpm and ten deep extraction wells pumping 1.0 gpm each are necessary to provide capture and extraction of the shallow and deep ground water at the site.

For the purposes of this evaluation, installation of thirteen shallow and ten deep extraction wells will be assumed. Also ground water extraction at a total rate of 18 gallons per minute will be assumed for the evaluation of ground water treatment alternatives. For an alternative in which ground water extraction would be combined with containment alternatives such as capping and sheet piling, the model indicated that the shallow aquifer would be dewatered after a period of one year, and after that time, only intermittent operation of the shallow ground water extraction system would be required. It has been assumed that the ground water extraction system would operate for the entire thirty-year post-closure period used for the soil/waste alternatives.

4.4.18 Alternative GW-4A - Ground Water Extraction Option Evaluation

Overall Protection of Human Health and the Environment - Use of extraction wells to remove ground water for treatment would be protective of both human health and the environment. Ground water would be extracted from the wells and piped directly to an on-site treatment system. The extraction system would be designed to comply with applicable ARARs, would be effective and reliable in the long-term and would have minimal short-term risks associated with extraction well installation.

Compliance with ARARs - Determination of compliance with chemical-specific ARARs is dependent on the development of site-specific remediation levels. While ground water and leachate contaminant levels exceed AWQC, modification of these criteria based on the relative lack of environmental impacts currently identified as being associated with ground water contamination is appropriate prior to their application as ground water ARARs. The proposed ground water extraction system has been developed to capture ground water contaminated at levels exceeding AWQC from both the shallow and deep aquifers. Therefore, it has been developed to provide compliance with chemical-specific ARARs, as presented in Table 4-20. Ground water extraction will also comply with wetland and coastal zone location-specific requirements, as listed in Table 4-21. Action-specific ARARs applicable to ground water extraction are limited to those ARARs listed in Table 4-22 which include well construction standards.

Long-Term Effectiveness and Permanence - Extractions wells are an effective and reliable means of extracting ground water. They are well-proven in their performance and can function with minimal maintenance.

Reduction of Toxicity, Mobility or Volume Through Treatment - The ground water extraction option does not provide treatment although it would be combined with a treatment option in a final alternative. By extracting contaminated ground water, the ground water's potential mobility is reduced.

Short-Term Effectiveness - Installation of extraction wells would present minimal short-term risks to on-site workers and would not be expected to result in any increased off-site risks to human health or the environment. Extraction wells could be implemented within a minimal time frame.

Implementability - The implementability of a ground water extraction system is expected to be good. Materials and services are readily available and minimal technical or administrative obstacles to implementation would be anticipated.

Cost - The major cost component associated with implementation of Alternative GW-4A is the cost of construction of the extraction wells. The estimated cost of Alternative GW-4A consists of $200,000 in direct capital costs, $28,000 in indirect capital costs, $28,000 in annual operation and maintenance costs ($430,000 net present value). The present worth value of this alternative, including contingency, is estimated at $790,000. A detailed cost estimate is presented in Appendix E.

4.4.19 Alternative GW-4B - Air Stripper Organic Treatment Option Description

This option involves the treatment of extracted ground water for volatile organics using air stripping. Air stripping is a mass transfer process in which a compound in solution in water is transferred to solution in a gas. The Henry's law constant, which relates the liquid phase concentration of a particular compound to the gas phase concentration, provides an indication of the strippability of a compound. Chlorinated hydrocarbons, including those detected at Site 09, and other compounds with Henry's law constants generally greater than 0.003 can effectively be removed by air stripping.

Manufacturers of packed tower air strippers design the systems to provide a specific removal efficiency given the influent concentrations for the contaminants of concern. As such, the design will vary from manufacturer to manufacturer, depending on type of packing material, column diameter, air-to-water ratio, tower height and other factors. Typical designs for air strippers are described below.

Air strippers can be configured as vertical stripping towers or horizontal, tray-type strippers. A typical tower-type system, consisting of an air stripping column filled with packing material and a blower system, is shown in Figure 4-7. An air stripping tower consists of tall, narrow tower filled with packing material. Extracted ground water is pumped to the top of the tower. As the water flows along the surfaces of the packing media within the tower, air is blown from the bottom of the tower, countercurrent to the direction of water flow. The volatile contaminants are transferred from the aqueous phase to the vapor phase during this process. In a tray-type stripper, contaminated water enters the tray stripper at the top and slowly works its way down through the stripper, from tray to tray. Within each tray, air bubbles flow up though the water, stripping the contamination from the water. No packing media are required within tray-type strippers.

In either type of system, volatile organic emissions may require emission controls in accordance with federal or state standards. If necessary, a system using activated carbon or off-gas incineration (catalytic oxidation) will be implemented to control VOC emissions.

PCBs and phenol were the only non-volatile organics detected in ground water or leachate at levels exceeding AWQC. If necessary, air stripping could be paired with a carbon adsorption polishing unit to address these contaminants as well.

4.4.20 Alternative GW-4B - Air Stripper Organic Treatment Option Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-4B is expected to provide overall protection of human health and the environment through treatment of volatile organics contaminants in the ground water. The long-term effectiveness and permanence and short-term effectiveness of the treatment system are expected to be good, and the system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs - The ability of the treatment system to treat volatile organics detected at levels exceeding AWQC is expected to be good, due to the high efficiency of air stripping in removing the volatile organic contaminants of concern. If semi-volatiles or PCBs were present in the extracted ground water at levels exceeding AWQC, air stripping could be supplemented with carbon adsorption to provide treatment of these constituents. Treatment system construction and operation would be in compliance with coastal zone location-specific requirements, as listed in Table 4-21. Emissions from the air stripping system would meet action-specific requirements related to air discharges listed in Table 4-22. If the extracted ground met the definition of a hazardous waste, RCRA treatment requirements listed in Table 4-22 would also apply. The treatment system would be required to treat the organic contaminants sufficiently to meet the applicable effluent discharge requirements, also listed in Table 4-22.

Long-Term Effectiveness and Permanence - The long-term risks associated with the residuals of ground water treatment by air stripping will be relatively small, since air stripping is a very efficient means of removing chlorinated hydrocarbons from the wastestream. Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties.

Reduction of Toxicity, Mobility or Volume Through Treatment - This alternative will provide a reduction in the toxicity of ground water through treatment. While air stripping does not destroy the contamination, it transfers it from the aqueous phase to the vapor phase where it can subsequently be destroyed by an off-gas treatment system.

Short-Term Effectiveness - Short-term risks to workers under this alternative are not expected to be significant. No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation. Off-gases will be treated prior to discharge as necessary under current state and federal regulations.

Implementability - The implementation of an air stripping treatment system is also expected to be good. Treatment units are widely available and easily constructed. Start-up is not expected to result in unanticipated technical problems. The implementation of air stripping will not impact the implementation of any future remedial actions. If additional treatment is required to treat non-volatile organics, the air stripping system could easily be paired with a carbon adsorption polishing unit. Operational activities will include maintaining the blower system and ensuring no clogging of the packing material occurs or periodic cleaning of the trays in a tray-type stripper. To minimize maintenance, the organic treatment system should follow the inorganic treatment system in the treatment train. Administrative feasibility is also expected to be good.

Cost - The major costs associated with Alternative GW-4B are the capital costs associated with the air stripping unit and associated operation and maintenance costs. The overall estimated cost includes $50,000 in direct capital costs, $7,000 in indirect capital costs and $1,300 in annual operation and maintenance costs ($20,000 net present value). The present worth value of this alternative, including contingency, is estimated at $93,000. A detailed cost estimate is presented in Appendix E.

4.4.21 Alternative GW-4C - UV Oxidation Organic Treatment Option Description

Alternative GW-4C involves the treatment of extracted ground water using UV oxidation, a technology which has recently been demonstrated in the USEPA's SITE program and which is becoming more commercially available.

UV oxidation is a process in which UV light and hydrogen peroxide chemically oxidize organic contaminants dissolved in water. A layout of a typical treatment system is provided in Figure 4-8. Hydrogen peroxide is converted in the presence of UV light to hydroxyl radicals, which are powerful oxidizers. Concurrently, organic molecules absorb energy from the UV light, making them more receptive to the hydroxyl radicals. The combined UV light and hydroxyl radicals promote rapid breakdown of organics into carbon dioxide and water without the creation of air emissions or residual waste streams.

UV oxidation is successful in treating most chlorinated hydrocarbons, although single-bonded compounds such as 1,1,1-trichloroethane are not always treated as successfully as double-bonded compounds. In a SITE demonstration of the perox-pure™ process, ground water contaminated with 1,000 ppb TCE, and 200 to 300 ppb of 1,1-dichloroethane, chloroform and 1,1,1-trichloroethane was treated with removal efficiencies of 81.8% to 98.3% (USEPA, 1993b). UV oxidation has also been used in treating ground water contaminated with vinyl chloride, pentachlorophenol and PCBs (USEPA, 1990b; USEPA, 1993c).

Self-contained UV oxidation units are manufactured by such vendors as Peroxidation Systems, Inc. and Ultrox International, Inc., and are available in various configurations. Each vendor's system operates under unique conditions and has its attributes and drawbacks.

Peroxidation Systems, Inc. (PSI) perox-pure™ units combine high-intensity UV light and hydrogen peroxide, which is easily soluble in water. The high-intensity lamps provide a shorter residence time than systems which use low-intensity lamps, thereby allowing treatment of high flow rates. The water temperature is raised approximately 5° per minute of residence time. Under some circumstances, increased water temperature has been linked to increased fouling of the quartz tubes that hold the UV lamps (Roy, 1990b). Operational problems include the precipitation of sediment on the quartz lamps, which can significantly reduce the system's destruction efficiency (Ibid.). Operation and maintenance of the PSI UV oxidation unit consists of provision of electricity, UV lamp replacement and maintenance of the hydrogen peroxide supply.

Other available systems include Ultrox International's system and VM Technology's UVOX system. The Ultrox system uses low-intensity UV lamps installed in chambers of a reactor. Ozone is introduced into the bottom of the chambers and hydrogen peroxide is also added to the influent. The ozone produces the hydroxyl radicals which oxidize the contaminants. Residual ozone is decomposed to oxygen in a separate treatment unit. The low intensity lamps generate less heat than the high intensity lamps of the PSI unit. Because the ozone is "bubbled" through the wastewater, single-bonded contaminants with high Henry's Law constants not treated as reliably in the PSI unit are stripped from the wastestream and subsequently treated in the ozone destruction unit. Maximum removal efficiencies in the SITE program demonstration ranged from 99 percent for trichloroethene to 65 and 85 percent for 1,1-dichloroethane and

1,1,1-trichloroethane, respectively. The ozone used in the process is generated on-site. Ozone is a toxic gas and must be handled accordingly (Roy, 1990a).

VM Technology's UVOX system provides UV oxidation without contact between the wastestream and the quartz sheaths covering the UV lamps. Compressed air is exposed to the UV lamps, creating ozone. The incoming wastestream is filtered to removed solid particles down to 5 microns. The wastestream and ozone are then mixed, with unreacted gas subsequently treated in a carbon bed. The treated wastewater flows through a carbon filtration system and filter before it is discharged (Roy, 1990b).

The final system design most applicable to ground water at Site 09 would be determined during the remedial design phase. Treatability studies could be required.

4.4.22 Alternative GW-4C - UV Oxidation Organic Treatment Option Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-4C is expected to provide overall protection of human health and the environment through treatment of organic ground water contaminants. The long-term effectiveness and permanence and short-term effectiveness are expected to be good, and the system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs - The ability of a UV oxidation treatment system to treat volatile organics detected at levels exceeding AWQC is expected to be good, based on treatment application reports. The system may also be effective in treating semi-volatiles or PCBs or could be supplemented with carbon adsorption to provide treatment of these constituents. Treatability studies would define the efficiency of the treatment system prior to implementation. Treatment system construction and operation would be in compliance with coastal zone location-specific requirements, as listed in Table 4-21. UV oxidation is not expected to result in the emission of any regulated contaminants and therefore action-specific requirements related to air discharges listed in Table 4-22 are not expected to be applicable to this alternative. If the extracted ground met the definition of a hazardous waste, RCRA treatment requirements listed in Table 4-22 would apply. The treatment system would be required to treat the organic contaminants sufficiently to meet the applicable effluent discharge requirements, also listed in Table 4-22.

Long-Term Effectiveness and Permanence - The long-term risks associated with UV oxidation will be minimal based on the system's ability to treat the organic contaminants of concern as well as the lack of treatment residuals. Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties.

Reduction of Toxicity, Mobility or Volume Through Treatment - This alternative will provide a reduction in the toxicity of identified organic ground water contaminants through treatment.

Short-Term Effectiveness - Short-term risks to workers under this alternative are not expected to be significant. Maintaining the hydrogen peroxide supply and the UV lamps are the major operation and maintenance activities. No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation based on the destruction of most contaminants of concern.

Implementability - The implementation of a UV oxidation system is also expected to be good, based on an increasing number of commercially available units. Modular and skid-mounted units are available. Start-up is not expected to result in unanticipated technical problems. The implementation of a UV oxidation treatment system is not expected to impact the implementation of any future remedial actions. Operation activities will include maintenance of the hydrogen peroxide supply and the UV lamps, as required. To minimize maintenance requirements, the organic treatment system should follow the inorganic treatment system in the treatment train. Administrative feasibility is also expected to be good.

Cost - The major costs associated with Alternative GW-4C are the capital costs associated with the UV oxidation unit and associated operation and maintenance costs, including hydrogen peroxide, maintenance parts and power. The overall estimated cost includes $210,000 in direct capital costs, $42,000 in indirect capital costs and $44,000 in annual operation and maintenance costs ($670,000 net present value). The present worth value of this alternative, including contingency, is estimated at $1,100,000. A detailed cost estimate is presented in Appendix E.

4.4.23 Alternative GW-4D - Precipitation Inorganic Treatment Option Description

Alternative GW-4D involves the treatment of inorganic ground water contaminants using chemical reduction and precipitation. Chemical precipitation is an inorganic removal method often used in industrial as well as ground water remediation applications.

For this evaluation, it is assumed that the chemical precipitation treatment system will include a filtration unit to remove gross solids prior to treatment and a flow equalization tank. The provision of an initial filtration system could result in reduced reagent costs and smaller equipment sizing for the remainder of the treatment train. A typical precipitation system includes the following:

- Reaction tank including mixers and pH control instrumentation;
- Chemical feed system, including a storage tank, mixers, level instrumentation and metering equipment;
- Clarifier;
- pH adjustment tank;
- Filter; and
- Solidification/stabilization system.

A schematic of a typical system is provided in Figure 4-9.

The extracted ground water flows from the filtration system, through the equalization tank, and into the reaction tank. In the reaction tank, a reagent is added to adjust the pH of the wastestream to the level required for optimum precipitation. The selection of an applicable precipitation reagent is dependent upon the flow rate, pH, pollutant loading, and waste/reagent compatibility.

Following the reaction tank, a flocculent such as an anionic or cationic polymer is added and the solution flocculated to aid in the settling of the metal precipitate. In the clarifier, flow is decreased to a point where solids with a specific gravity greater than that of the liquid settle to the bottom. The supernatant is drawn off and discharged to a pH adjustment tank for neutralization. The solids are discharged to a holding tank for subsequent dewatering. Dewatering is accomplished using mechanical dewatering equipment such as a filter press. Once dewatered the sludge is stabilized prior to off-site landfill disposal in accordance with federal and state disposal requirements.

4.4.24 Alternative GW-4D - Precipitation Inorganic Treatment Option Evaluation

Overall Protection of Human Health and the Environment - Option GW-4D is expected to provide overall protection of human health and the environment through treatment of inorganic ground water contaminants. The long-term effectiveness and permanence and short-term effectiveness are expected to be good, and the system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs - The ability of a chemical precipitation treatment system to treat inorganics detected at levels exceeding AWQC is expected to be good. Treatment system construction and operation would be in compliance with coastal zone location-specific requirements, as listed in Table 4-21. Chemical precipitation produces a sludge which requires subsequent disposal off-site. If the extracted ground water or sludge meet the definition of a hazardous waste, RCRA treatment or disposal requirements listed in Table 4-22 would apply. The treatment system would be required to treat the inorganic contaminants sufficiently to meet the applicable effluent discharge requirements, also listed in Table 4-22.

Long-Term Effectiveness and Permanence - The long-term risks associated with chemical precipitation will be minimal based on the system's ability to treat the contaminants of concern. However, the treatment system does produce a sludge that will require hazardous waste characterization and appropriate disposal. Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties.

Reduction of Toxicity, Mobility or Volume Through Treatment - This alternative will provide a reduction in the toxicity of identified inorganic ground water contaminants through treatment. The volume of contaminated media is reduced through removal of contaminants from the ground water and subsequent production of a concentrated sludge residual.

Short-Term Effectiveness - Short-term risks to workers under this alternative are not expected to be significant. Maintenance of chemical supplies and sludge handling are the major operation and maintenance activities associated with the chemical precipitation system. No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation.

Implementability - A chemical precipitation system should be easily implemented. Start-up is not expected to result in unanticipated technical problems. Its implementation is not expected to impact the implementation of any future remedial actions. Operational activities include maintenance of the chemical supplies and sludge handling. Administrative feasibility is also expected to be good.

Cost - The major costs associated with Alternative GW-4D are the capital costs associated with the construction of a chemical precipitation unit and associated operation and maintenance costs, including chemical supply costs. The overall estimated cost includes $150,000 in direct capital costs, $30,000 in indirect capital costs and $48,000 in annual operation and maintenance costs ($730,000 net present value). The present worth value of this alternative, including contingency, is estimated at $1,100,000. A detailed cost estimate is presented in Appendix E.

4.4.25 Alternative GW-4E - Membrane Microfiltration Inorganic Treatment Option Description

Alternative GW-4E involves the treatment of inorganic ground water contaminants using membrane microfiltration. Membrane microfiltration is a physical process for removing fine particulate matter from a wastestream. Since ground water at Site 09 tends to be silty when pumped from an extraction well, a significant amount of suspended particulates are present in the ground water which could be removed using membrane microfiltration. When low flow sampling methodologies were used during the Phase II RI, significant reductions in inorganic concentrations were observed, and filtered ground water sample results were comparable to unfiltered sample results. Since membrane microfiltration utilizes a filter material with even smaller openings than the filter used in the field (0.1 microns versus 0.45 microns), it could be successful in removing inorganics which passed through the field filter. Therefore, determination of the degree to which membrane microfiltration could remove particulates which were present in filtered ground water samples would require treatability study testing.

A membrane microfiltration treatment system developed by E.I. DuPont de Nemours & Company (DuPont) has been included in the U.S. EPA's Superfund Innovative Technology Evaluation (SITE) program. The system is designed to remove solid particles from liquid wastes, forming filter cakes typically ranging from 40 to 60 percent solids. It consists of an automatic pressure filter (Oberlin) combined with DuPont's special Tyvek filter material (Tyvek T-980) made of spun-bonded olefin. A schematic of the system is presented in Figure 4-10.

The microfiltration unit operates in a cyclical manner. The waste feed enters an upper chamber and is pumped through the filter fabric. The fabric allows water and solids less than about one tenth of a micron in diameter to pass through the openings in the fabric. Filtered solids accumulate on the fabric, forming a filter cake, while the filtrate accumulates in a lower chamber. Air is fed into the upper chamber at about 45 pounds per square inch and used to further dry the cake and remove any remaining liquid. When the cake has been dried, the upper chamber is lifted and the filter cake discharged. The entire system is enclosed and therefore can be used to treat wastestreams containing volatile organics.

Pilot tests using this technology have been conducted at the Palmerton Zinc Superfund site in Palmerton, Pennsylvania, where ground water is contaminated with dissolved heavy metals such as cadmium, lead and zinc. The tests produced a 35 to 45 percent-solids filter cake, and a filtrate with non-detectable levels of heavy metals. The filter cake also passed TCLP analysis to render it a non-hazardous waste (U.S. EPA, 1989d).

4.4.26 Alternative GW-4E - Membrane Microfiltration Inorganic Treatment Option Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-4E is expected to provide overall protection of human health and the environment through treatment of inorganic ground water contaminants. The long-term effectiveness and permanence and short-term effectiveness are expected to be good, and the system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs - The ability of the membrane microfiltration treatment system to treat inorganics detected at levels exceeding AWQC is expected to be good, although treatability studies would be required to confirm its effectiveness. Treatment system construction and operation would be in compliance with coastal zone location-specific requirements, as listed in Table 4-21. The sludge produced as a result of the microfiltration process requires subsequent disposal off-site. If the extracted ground water or sludge meet the definition of a hazardous waste, RCRA treatment or disposal requirements listed in Table 4-22 would apply. The treatment system would be required to treat the inorganic contaminants sufficiently to meet the applicable effluent discharge requirements, also listed in Table 4-22.

Long-Term Effectiveness and Permanence - The long-term effectiveness of the membrane microfiltration system is expected to be good. However, the treatment system produces a sludge that will require hazardous waste characterization and appropriate disposal. Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties.

Reduction of Toxicity, Mobility or Volume Through Treatment - This alternative will provide a reduction in the toxicity of undissolved inorganic ground water contaminants through treatment, although it provides no treatment of dissolved contaminants. The volume of contaminated media is reduced through removal of the inorganic particles from the ground water and subsequent production of a concentrated sludge residual. Since no chemicals are added, the sludge volume produced by this treatment system is generally less than that produced by chemical addition treatment systems. The sludge produced by the DuPont treatment system has passed TCLP tests at a Superfund site, thereby allowing for its disposal as a non-hazardous waste.

Short-Term Effectiveness - Short-term risks to workers under this alternative are not expected to be significant. Maintenance requirements for the system are not significant and consist mainly of periodic membrane replacement and sludge handling. No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation.

Implementability - The implementation of a membrane microfiltration system is good. Start-up is not expected to result in unanticipated technical problems, although the treatment system could experience clogging, depending on the levels of inorganics in the ground water. Its implementation is not expected to impact the implementation of any future remedial actions. Operational activities include maintenance of the membranes and sludge handling. The membranes have a limited life expectancy and may be subject to fouling. Administrative feasibility is expected to be good.

Cost - The major costs associated with Alternative GW-4E are the capital costs associated with the addition of the membrane microfiltration unit and associated operation and maintenance costs, including sludge disposal costs. The overall estimated cost includes $370,000 in direct capital costs, $75,000 in indirect capital costs and $550,000 in annual operation and maintenance costs ($8,500,000 net present value). The present worth value of this alternative, including contingency, is estimated at $11,000,000. A detailed cost estimate is presented in Appendix E.

4.4.27 Alternative GW-4F - Discharge to Surface Water Option Description

Alternative GW-4F involves the discharge of treated ground water to surface water, which in this case would be Allen Harbor or a tributary to Allen Harbor. Discharge could occur directly, via a discharge pipe. The discharge rate would be equal to the extraction rate, estimated at 18 gallons per minute. Implementation of discharge to the surface water is expected to have little, if any, effect on the ground water extraction and treatment system.

4.4.28 Alternative GW-4F - Discharge to Surface Water Option Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-4F would provide overall protection of human health and the environment when combined with ground water extraction and treatment. The long-term effectiveness and permanence of this option are expected to be good, due to its simplicity, and the discharge system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs - The water quality of the effluent from the treatment process will have to meet AWQC for discharge to surface water, as indicated in Table 4-20. The discharge system will be required to comply with coastal zone requirements listed in Table 4-21 and action-specific requirements related to discharge and construction listed in Table 4-22.

Long-Term Effectiveness and Permanence - The long-term risks associated with discharge to surface water will be minimal, provided the treatment system is operating properly. Long-term operation and maintenance of the discharge piping is not expected to pose any major technical problems. Long-term monitoring of the discharge water quality will be required.

Reduction of Toxicity, Mobility or Volume Through Treatment - This alternative is not expected to significantly impact the extraction or treatment system; therefore, it has little impact on the toxicity, mobility or volume of contamination.

Short-Term Effectiveness - Short-term risks to workers under this alternative are not expected to be significant since no construction is required. Maintenance of the system will require maintenance of the piping and discharge monitoring. No significant added risks to the adjacent community or the environment are anticipated.

Implementability - The technical implementation of a discharge to surface water system is very good based on the short distance to a discharge point. Maintenance of the system will be limited. Continued monitoring of the discharged water quality will be required. Administrative feasibility of discharging treated ground water to surface water depends on the treatment system's ability to meet surface water discharge criteria.

Cost - The major costs associated with Alternative GW-4F are the on-going maintenance and discharge monitoring costs associated its implementation. The overall estimated cost includes \$5,800 in direct capital costs, \$900 in indirect capital costs and \$24,000 in annual operation and maintenance costs (\$370,000 net present value). The present worth value of this alternative, including contingency, is estimated at \$450,000. A detailed cost estimate is presented in Appendix E.

4.5 Ground Water/Leachate Alternative Comparative Evaluation

A comparative analysis of the ground water/leachate alternatives is conducted to evaluate the significant differences between the alternatives based on the threshold and balancing criteria. Tables 4-23 through 4-30 comparatively summarize the alternative evaluations conducted strictly on the basis of ground water/leachate considerations for each of the evaluation criteria. A determination of the overall protectiveness of the ground water/leachate alternatives will be dependent on the final determination of ground water cleanup standards for Site 09 as well as a consideration of how the ground water/leachate alternative will relate to the remedial alternatives selected for the other environmental media. These considerations are discussed further in Section 5.

4.5.1 Overall Protection of Human Health and the Environment

A comparative analysis of the remedial alternatives with respect to overall protection of human health and the environment is presented in Table 4-23.

Alternative GW-4, ground water extraction/treatment/discharge, could be considered to provide the greatest degree of overall protection of human health and the environment through its active remediation of ground water contamination, however its permanence once treatment is discontinued is not ensured. For the extraction, treatment, and discharge options evaluated under this alternative, all options provided relatively comparable protection of human health and the environment.

Alternative GW-3, containment, would be protective in terms of limiting migration of ground water/leachate from the landfill area. The capping option would limit leachate seeps while the sheet piling option would limit ground water flow through the landfill area. The long-term effectiveness of each alternative would be good, although some increased risks to on-site workers would occur during construction.

Alternative GW-2, limited action, would provide protection against future impacts to human health or the environmental through the elimination of potential human exposures due to on-site well construction (deed restriction option) and through long-term monitoring to identify environmental degradation which could be attributable to ground water migration (long-term monitoring option). This alternative does not address potential human health and environmental risks associated with the presence of leachate seeps.

Alternative GW-1, no action, would provide the least protection of human health and the environment. It does not limit future site use, monitor for environmental impacts associated with contaminant migration or provide containment or treatment of ground water/leachate. It would not meet remedial action objectives.

4.5.2 Compliance with ARARs

A comparative analysis of the remedial alternatives with respect to compliance with ARARs is presented in Table 4-24.

Determination of the alternatives' compliance with chemical-specific ARARs is dependent upon the development of modified AWQC for application as ground water ARARs. Alternative GW-4 and its treatment options are the only alternatives which provide a potential for reduction of ground water contaminant levels for contaminants detected at levels exceeding AWQC. However, long-term maintenance of reduced levels for these contaminants is not guaranteed once the remedial system is discontinued. All other alternatives would be constructed in accordance with location-specific criteria, including those which govern activities in coastal zone and wetland areas. All remedial actions would also comply with the applicable action-specific ARARs, as indicated in Table 4-24.

4.5.3 Long-Term Effectiveness and Permanence

A comparative analysis of the remedial alternatives with respect to long-term effectiveness and permanence is presented in Table 4-25.

Alternatives GW-2 and GW-3 would both be expected to provide good long-term effectiveness. The limited action alternative would provide a means of monitoring the site over the long-term to identify any changes in ground water, sediment or surface water quality attributable to the site which could result in environmental impacts while the containment alternative would provide reliable barriers to ground water or leachate migration in the long-term. While Alternative GW-4 would be effective during operation, it would not be a permanent solution if ground water were to resaturate subsurface wastes after discontinuation. The extraction, treatment and discharge options are all expected to be effective in the long-term, although the UV oxidation and membrane microfiltration options (GW-4C and GW-4E, respectively) would require treatability studies to demonstrate their effectiveness. Air stripping (GW-4B) is effective and easily operated and maintained. Chemical precipitation (GW-4D) is also expected to be effective in the long-term treatment of inorganics. The no action alternative offers the least long-term effectiveness and permanence.

4.5.4 Reduction of Toxicity, Mobility or Volume Through Treatment

A comparative analysis of the remedial alternatives with respect to reduction of toxicity, mobility or volume of contamination through treatment is presented in Table 4-26.

Alternative GW-4 is the only alternative which provides a reduction of contaminant toxicity through treatment. The treatment options are all expected to be effective in treating the identified contaminants, although UV oxidation (Option GW-4C) and membrane microfiltration (Option GW-4E) would require treatability studies to demonstrate their effectiveness. Alternative GW-3, including the capping and sheet piling options, provides a reduction in the mobility of contaminated ground water but utilizes containment features rather than treatment to achieve this reduction in mobility. Alternatives GW-2 and GW-1 provide no reduction in toxicity, mobility or volume through treatment.

4.5.5 Short-Term Effectiveness

A comparative analysis of the remedial alternatives with respect to short-term effectiveness is presented in Table 4-27.

Alternative GW-2 is the most effective alternative in the short-term, providing a means of monitoring compliance with remedial action objectives but resulting in no increases in short-term risks. Option GW-2A allows for the long-term monitoring of ground water, surface water and sediment quality to ensure future degradation would not occur which would result in ecological impacts. Option GW-2B would meet remedial action objectives with respect to minimizing future human exposures to contaminated ground water. Alternative GW-1 also poses no increased short-term risks but does not achieve remedial action objectives.

Alternative GW-4 also provides a means of complying with remedial action objectives within a short time frame with minimal risk incurred. Of the organic treatment options, air stripping (GW-4B) is more effective in the short-term than UV oxidation (GW-4C) due to the availability of treatment systems and the ease of operation, with no handling of waste materials required. For inorganic treatment options, membrane microfiltration (GW-4E), may require less handling of chemical supplies but may not be as quickly implemented as precipitation (GW-4D). Both ground water extraction (GW-4A) and discharge to surface water (GW-4F) could be quickly implemented and effective in the short-term.

Alternative GW-3 achieves remedial action objectives within a relatively short time frame but site disruption results in increased short-term risks. These risks could be minimized through the use of personnel protective equipment.

4.5.6 Implementability

A comparative analysis of the remedial alternatives with respect to implementability is presented in Table 4-28.

Alternative GW-1 would be the most implementable since it requires no action other than a five-year review. Alternative GW-2 would be next in terms of implementability, requiring initiation of long-term monitoring and deed restrictions but no on-site construction activities. Neither Alternative GW-1 nor GW-2 would limit the implementation of other remedial actions at the site.

Alternatives GW-3 and GW-4 would both require disruption of the site for implementation. However, each alternative and the associated options pose no major difficulty in implementation. The containment options of Alternative GW-3 could limit the implementation of other remedial actions in the future. For Alternative GW-4, air stripping (GW-4B) would be more easily implemented due to their commercial availability and ease of operation than would UV oxidation (GW-4C). Similarly, chemical precipitation (GW-4D) would be more easily implemented than membrane microfiltration (GW-4E). Ground water extraction (GW-4A) and discharge to surface water (GW-4F) would both be easily implemented. Option GW-4F would require long-term monitoring in accordance with discharge regulations.

4.5.7 Cost

A comparative analysis of the remedial alternatives with respect to cost is presented in Table 4-29. The no action alternative is the least costly alternative, the only cost being the nominal cost associated with a five-year review. Alternative GW-2 follows, with a total estimated present worth cost of $1,800,000. Alternatives GW-3 and GW-4 would be costly to implement, depending on the options selected for each alternative. The total cost of containment under Alternative GW-3 would range from $3,800,000 (for capping alone) to $11,000,000 (for a RCRA Subtitle C cap and sheet piling). For the ground water treatment options of Alternative GW-4, air stripping offers significant cost savings over UV oxidation, and precipitation offers significant cost savings over membrane microfiltration.

4.6 Sediment Alternatives

While potential environmental risks have been identified as being associated with sediments in the Allen Harbor Watershed, the risks associated with sediment contamination believed to be directly applicable to the landfill (i.e., risks associated with contaminated sediments identified at the toe of the landfill face) may not be significant due to the limited areal extent of sediment materials at the toe of the landfill.

4.6.1 Alternative SD-1 - No Action Alternative Description

In accordance with the NCP, the no-action alternative is considered. This alternative would involve no remedial response activities with respect to sediment contamination at Allen Harbor Landfill. Because contaminated sediments would remain under this alternative, a five-year review of the no action decision would be required.

An evaluation of Alternative SD-1 with respect to location-specific ARARs and TBCs is presented in Table 4-30. No chemical-specific ARARs/TBCs were identified for sediments and, due to the lack of actions associated with the no action alternative, no action-specific ARARs/TBCs are applicable.

4.6.2 Alternative SD-1 - No Action Alternative Evaluation

Overall Protection of Human Health and the Environment - Due to the limited exposure pathway posed by contaminated sediments to humans (based on the physical barriers to access as well as the limited areal extent of contaminated sediments at the toe of the landfill face), the no action alternative is considered to be protective of human health. While the ecological risk assessment concluded that sediments at the toe of the landfill face did pose a potential for ecological risk, due to the presence of metals and pesticides, the apparent limited extent of sediment-type materials along the toe of the landfill face will limit the exposure pathway posed by the sediments. While a potential risk for negative ecological impact was identified in the Allen Harbor Risk Assessment Pilot Studies (ERLN, 1994), risk estimates (toxic units or TUs) were less than 1, which is typically used as the upper acceptable risk ratio. Therefore, this alternative's long-term effectiveness and compliance with ARARs would be dependent upon a continued lack of identification of impacts to the environment in the future. This alternative does not include any long-term monitoring to identify any potential changes to sediment quality, should they occur in the future. Implementation of this alternative results in no short-term impacts to the site.

Compliance with ARARs - An evaluation of the no action alternative with respect to federal and state location-specific ARARs/TBCs is presented in Table 4-30. Since the no action alternative involves no actions which impact coastal or wetland areas, location-specific ARARs are met. No chemical-specific or action-specific ARARs are applicable to this alternative.

Long-Term Effectiveness and Permanence - While a residual risk to the environment remains as a result of this alternative, the potential for risk due to contaminated sediments at the toe of the Allen Harbor Landfill face is limited by the limited areal extent of sediment materials in this area. However, due to the residual risk which would be associated with the no action alternative, a five-year review of the no action decision would be required under the NCP.

Reduction of Toxicity, Mobility, or Volume through Treatment - The no action alternative does not include any treatment methods other than naturally occurring degradation or attenuation processes. Therefore, the alternative offers no reductions in the toxicity, mobility, or volume of sediment contamination through treatment.

Short-Term Effectiveness - The no action alternative does not present any increased short-term risks due to the lack of activities associated with its implementation.

Implementability - The no action alternative would require no implementation other than a five-year review of the no action decision. Its implementation would not limit the future implementation of additional remedial actions.

Cost - The cost associated with the no action alternative would be the nominal cost associated with the five-year review.

4.6.3 Alternative SD-2 - Limited Action Alternative Description

Alternative SD-2 was developed as a limited action option which provides no active remediation but limits potential risks to human health and the environment through the implementation of institutional controls such as implementation of a long-term monitoring program to monitor potential changes in sediment quality.

An evaluation of Alternative SD-2 with respect to federal and state location-specific ARARs/TBCs is presented in Table 4-30. No chemical-specific or action-specific ARARs were identified for the limited action alternative.

4.6.4 Alternative SD-2 - Limited Action Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative SD-2 provides protection of human health and the environment by providing a mechanism for monitoring potential increases in environmental risks which could be associated with future degradation of sediment quality, although it provides no protection against disruption of existing contaminated sediments. The limited action alternative is effective in the short-term and would also be effective in the long-term provided no ecological impacts due to sediment quality degradation are identified in the future.

Compliance with ARARs - Since the limited action alternative involves no actions which impact coastal or wetland areas, it complies with location-specific ARARs, as indicated in Table 4-30. No chemical-specific or action-specific ARARs are applicable to the limited action alternative.

Long-Term Effectiveness and Permanence - Alternative SD-2 relies on the use of institutional controls to identify changing site conditions which may present increased risks to the environment. It provides no protection against potential disruption of contaminated sediments due to wave or storm action. Since contaminated sediments would remain in-place, a five-year review of Alternative SD-2 would be required.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative SD-2 provides no treatment of contaminated sediment and therefore no reduction in contaminant toxicity, mobility or volume.

Short-Term Effectiveness - Alternative SD-2 would be relatively effective in the short-term, due to the lack of activities associated with its implementation and therefore the lack of short-term risks which would result from implementation. Continued monitoring would ensure that remedial action objectives continue to be achieved.

Implementability - Implementation of an alternative involving institutional controls such as a monitoring program would be relatively easy. Implementation of Alternative SD-2 would not be expected to limit the implementation of future remedial actions.

Cost - Costs associated with the implementation of Alternative SD-2 would be those associated with the implementation of a monitoring program. The cost of implementation for Alternative SD-2 is estimated to include $30,000 in annual operation and maintenance costs

($460,000 net present value). The present worth value of this alternative, including contingency, is estimated at $550,000. A detailed cost estimate is presented in Appendix E.

4.6.5 Alternative SD-3 - Containment Alternative Description

Alternative SD-3 was developed as an alternative which provides containment of contaminated sediments, thereby limiting potential human exposures and potential risks to the environment. It is assumed to consist of the placement of a stone revetment over the toe of the landfill to contain any contaminated sediments and to eliminate the existing contaminant exposure pathways. The presence of the revetment at the toe of the landfill would provide protection against disruption of contaminated sediments due to storm action.

An evaluation of Alternative SD-3 with respect to federal and state location-specific and action-specific ARARs/TBCs is presented in Tables 4-31 and 4-32, respectively. No chemical-specific ARARs were identified as being applicable to Alternative SD-3.

4.6.6 Alternative SD-3 - Containment Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative SD-3 provides protection of human health and the environment by eliminating the exposure pathway which presents potential risks to the environment as well as by limiting potential human exposures to contaminated sediments.

If degradation of sediment quality was determined to be attributable to contaminant migration from Allen Harbor Landfill, location-specific ARARs could be violated. The containment alternative could result in some increased short-term risks due to the disruption of contaminated sediments during construction of the containment system. It would be effective in the long-term in limiting exposures to contaminated sediments as well as by minimizing the potential disruption of areas of contaminated sediments due to wave or storm action.

Compliance with ARARs - Alternative SD-3 would impact coastal areas and wetlands and, therefore, construction activities would have to be conducted in accordance with location-specific ARARs as listed in Table 4-31. If construction activities cannot be limited to within the toeprint of the existing landfill area, mitigation of any impacted wetlands may be required.

Construction would also be conducted in a manner protective of migratory birds, as indicated in Table 4-32.

Long-Term Effectiveness and Permanence - Alternative SD-3 relies on the use of a containment system to reduce potential risks to the environment. The containment system would be expected to be effective in the long-term, requiring minimal maintenance. Since contaminated sediments would remain in-place, a five-year review of Alternative SD-3 would be required.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative SD-3 provides no treatment of contaminated sediment and therefore no reduction in contaminant toxicity, mobility or volume. However, a reduction in the mobility of contaminated sediments would be provided by the containment features of this alternative.

Short-Term Effectiveness - Alternative SD-3 could result in increases in short-term risks due to the disruption of the contaminated sediments during construction of the containment measure. However, remedial response objectives could be achieved within a relatively short time frame.

Implementability - Implementation of the containment alternative would be relatively easy from a technical standpoint. The presence of the containment system could affect the implementation of future remedial actions, if needed.

Cost - Costs associated with the implementation of Alternative SD-3 would be those associated with the construction of the containment system. The cost of implementation for Alternative SD-3 is estimated to include $380,000 in direct capital costs, $53,000 in indirect capital costs and $600 in annual operation and maintenance costs ($9,000 net present value). The present worth value of this alternative, including contingency, is estimated at $530,000. A detailed cost estimate is presented in Appendix E.

4.7 Sediment Alternative Comparative Evaluation

A comparative analysis is conducted to evaluate the significant differences between the alternatives based on the threshold and balancing criteria. Tabular comparisons of the alternatives based on the seven evaluation criteria are presented in Tables 4-33 through 4-39.

4.7.1 Overall Protection of Human Health and the Environment

A comparative analysis of the remedial alternatives with respect to overall protection of human health and the environment is presented in Table 4-33.

Alternative SD-3, containment, provides the greatest protection of human health and the environment by containing the contaminated sediments and eliminating environmental exposure pathways. It also provides a benefit in terms of providing protection of the shoreline area against storm effects. It could be implemented within a short time frame with minimal increases in risk during the implementation period. It would provide good long-term effectiveness and its construction would be in compliance with location-specific ARARs.

Alternative SD-2, limited action, provides protection of the environment through continued monitoring of sediment quality to allow for the identification of potential future sediment degradation that could result in measurable ecological effects. It does not provide protection against existing exposure pathways or against the effects of storms. Alternative SD-1, no action, is the least protective alternative.

4.7.2 Compliance with ARARs

A comparative analysis of the remedial alternatives with respect to compliance with ARARs is presented in Table 4-34.

No chemical-specific ARARs were identified for sediments and no action-specific ARARs were identified for the alternatives undergoing evaluation. Alternative SD-3 would be the only alternative involving an action which would be required to comply with location-specific ARARs applicable to activities in a coastal zone or wetland area. Construction would be conducted in accordance with these location-specific ARARs.

4.7.3 Long-Term Effectiveness and Permanence

A comparative analysis of the remedial alternatives with respect to long-term effectiveness and permanence is presented in Table 4-35.

Alternative SD-3 provides the greatest degree of long-term effectiveness and permanence through its containment features. Alternative SD-2 provides a means of monitoring long-term effectiveness through its monitoring program but provides no protection against disruption of the sediments due to storm events and does not address the ecological risk posed by the presence of the contaminated sediments. Alternative SD-1 provides the least long-term effectiveness and permanence. Each of the alternatives would require a five-year review since the contaminated sediments would remain in-place.

4.7.4 Reduction in Toxicity, Mobility or Volume Through Treatment

A comparative analysis of the remedial alternatives with respect to reductions in toxicity, mobility or volume through treatment is presented in Table 4-36.

None of the sediment alternatives include treatment, therefore no reductions in contaminant toxicity, mobility or volume are achieved through treatment. Alternative SD-3 is the only alternative to provide a reduction in contaminant mobility through its containment features.

4.7.5 Short-Term Effectiveness

A comparative analysis of the remedial alternatives with respect to short-term effectiveness is presented in Table 4-37.

All alternatives are effective in the short-term. Alternative SD-3 results in increased short-term risks during construction of the containment system but is the only alternative to meet remedial action objectives.

4.7.6 Implementability

A comparative analysis of the remedial alternatives with respect to implementability is presented in Table 4-38.

Alternative SD-1 is the most easily implemented since it involves no remedial actions. Alternative SD-2 would also be easily implemented, requiring initiation of a sediment monitoring program. Alternative SD-3 requires the greatest implementation effort due to the construction of the containment system. The presence of the containment system could impact the implementation of other remedial actions.

4.7.7 Cost

A comparative analysis of the remedial alternatives with respect to cost is presented in Table 4-39. The no action alternative is the least costly alternative, the only cost being the nominal cost associated with a five-year review. Alternative SD-2 and SD-3 would be comparative in terms of cost to implement, with a total estimated present worth cost for Alternative SD-2 of $550,000 and for Alternative SD-3 of $530,000.

4.8 Sensitivity Analysis

A sensitivity analysis was conducted to assess the effect that variations in specific assumptions made during alternative development and assessment could have on the total estimated remedial cost. The main uncertainty factor which is applicable to the remedial alternatives and associated options is the uncertainty associated with the discount factor over the life of the remedy.

The discount rate can vary from the 5% rate used in the cost evaluation. Alternatives with large O&M cost components and extended remedial periods can be significantly impacted by a variation in the discount rate. The sensitivity analysis has been conducted assuming a variation in the annual discount rate, with total present worth costs estimated for each alternative at annual discount rates of 3% and 10%. The resultant impacts to remedial costs are summarized in Table 4-40.

5.0 RECOMMENDATIONS AND CONCLUSIONS

5.1 Site-Wide Assessment

Based on the remedial alternatives evaluated for the individual environmental media at Site 09, numerous comprehensive alternatives consisting of various combinations of media-specific alternatives could be developed. While it is not possible to describe and evaluate each combination of alternatives, a discussion of certain comprehensive alternative types, taking into consideration the interactions between the environmental media, is appropriate to the development of a final remedial alternative recommendation for the site. The general alternatives evaluated include:

- No Action
- Limited Action
- Containment
- Containment with Ground Water Treatment

The general descriptions of the alternatives presented below are not intended to preclude other possible combinations of media-specific alternatives. Rather, they are presented to allow a presentation of how the alternatives could be combined to form site-wide remedial alternatives.

A summary of the components which are included in each of the comprehensive alternatives described below is presented in Table 5-1.

5.1.1 Alternative 1 - No Action

A comprehensive no action alternative would consist of no action with respect to soil/waste, ground water/leachate and sediment. It would not provide overall protection of human health and the environment, would not achieve remedial action objectives and would not be protective in the long-term.

5.1.2 Alternative 2 - Limited Action

A comprehensive limited action alternative would consist of institutional controls for soil/waste, ground water/leachate and sediment. It could consist of the following:

- Deed restrictions to limit future exposures to subsurface waste materials and contaminated ground water

- Fencing to prevent human exposures to contaminated surface materials

- Long-term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present increased ecological risks

While this alternative would be protective of human health in terms of limiting potential human exposures to site contamination, it would not ensure the long-term protection of the environment. No reduction in surficial contaminant migration, leachate seeps, potential ground water migration, or exposures of surficial contaminants to ecological receptors would be achieved. The presence of fencing and residual contamination would prohibit future recreational use of the site and could impact the value of the site as a conservation area, both preferred future site uses specified in the Base Reuse Plan.

5.1.3 Alternative 3 - Containment

A comprehensive containment alternative would consist of containment measures combined with institutional controls and long-term monitoring, in accordance with a RCRA hybrid closure approach. A possible containment alternative would consist of the following:

- Landfill cap consisting of a native soil cap or single-barrier cap (Alternative S/W-3B, RCRA Hybrid cap) and storm water discharge monitoring

- Containment of landfill toe sediments

- Deed restrictions to limit future exposures to subsurface waste materials and contaminated ground water, and prevent disruption of the capping system

- Long-term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present ecological risks

This alternative would provide overall protection of human health and the environment. Direct exposures to contaminated surface materials would be eliminated by the presence of the cap. The cap would also reduce the potential for leachate seeps to discharge directly to Allen Harbor, especially if the single-barrier cap was utilized. By providing sediment containment along the landfill toe, the sediment exposure pathway which has been associated with potential ecological risks would be eliminated and long-term protection of the cap against storm events would be provided. The native soil cap would be more amenable to reestablishment of existing vegetation; the single-barrier cap planted with shallow-rooted grasses would provide a meadow-type habitat. Long-term monitoring would allow for the identification of any changes in environmental quality which could result in increased ecological impacts. Implementation of this alternative would be compatible with future site use as a recreation/conservation area.

5.1.4 Alternative 4 - Containment With Ground Water Treatment

This comprehensive alternative consists of containment features coupled with active ground water remediation. It could consist of the following:

- RCRA hybrid (single-barrier) cap and storm water discharge monitoring
- Sheet piling vertical barrier to contain the contaminated ground water and limit the volume of contaminated ground water requiring treatment
- Ground water extraction, air stripping, and chemical precipitation with discharge to surface water
- Long-term ground water monitoring
- Deed restrictions to limit future exposures to subsurface waste materials

This alternative would also be protective of human health and the environment although the reductions in potential ecological risk associated with ground water containment and remediation may not be justified by the costs associated with providing vertical containment and ground water treatment. Also, when the active treatment of ground water would be discontinued, re-contamination of ground water could occur. Although containment systems would be in-place to limit the accumulation of ground water within the landfill area, no containment system is totally impervious. The slow leakage of ground water through the vertical barrier and/or cap could eventually result in the re-accumulation of ground water within the waste layer in the southern portion of the site.

5.1.5 Comparative Evaluation of Comprehensive Alternatives

A comparison of the four comprehensive remedial alternatives described in Sections 5.1.1 through 5.1.4 against the alternative evaluation criteria is presented in Tables 5-2 through 5-8. A brief discussion of the relative merits of the alternatives with respect to the evaluation criteria is presented below.

Overall Protection of Human Health and the Environment - A comparison of comprehensive alternatives with respect to overall protection of human health and the environment is presented in Table 5-2. Each of Alternatives 3 and 4 are expected to be protective of human health and the environment. They each address surficial soil contamination, leachate seeps, and sediment contamination through the provision of physical barriers to exposure. Alternative 3 provides a mechanism for long-term monitoring of potential ecological impacts due to contaminated ground water migration while Alternative 4 provides active ground water remediation. Alternative 2 provides no protection of the environment while Alternative 1 is not protective of either human health or the environment.

Compliance with ARARs - A comparison of comprehensive alternatives with respect to compliance with ARARS is presented in Table 5-3. A determination of the alternatives' compliance with chemical-specific ARARs is dependent upon the development of modified AWQC for use as final ground water ARARs. Alternative 4 is the only alternative which utilizes treatment to address contaminants present in ground water and leachate at levels exceeding AWQC. However, based on the general lack of ecological impacts which are clearly attributable to ground water migration, an alternative which does not utilize active treatment could be protective. Also, the permanence of Alternative 4 in maintaining treatment levels following discontinuation of treatment is not assured due to the continued presence of subsurface waste materials and the potential for resaturation of those materials. Both Alternatives 3 and 4 would achieve chemical-specific soil ARARs/TBCs. Alternatives 1 and 2 would not achieve chemical-specific soil ARARs/TBCs.

Each of the alternatives would be constructed in accordance with location-specific coastal zone and wetland considerations. Action-specific ARARs would be followed in the design, construction and operation of remedial actions.

Long-Term Effectiveness and Permanence - A comparison of comprehensive alternatives with respect to long-term effectiveness and permanence is presented in Table 5-4. Alternatives 3 and 4 are expected to be effective in the long-term, providing protection against surface soil, leachate seep, and sediment contamination and providing a means of monitoring the potential for future ecological impacts. While Alternative 4 provides ground water treatment and thereby minimizes the potential for ground water migration to result in ecological impacts during its operational period, it may not provide permanent protection against re-contamination of the ground water and ground water migration once treatment is discontinued. Alternative 4 also involves long-term ground water treatment system operation, while Alternative 3 requires implementation of a long-term monitoring program. Alternative 2 would not be effective in the long-term in protecting the environment. Alternative 1 provides the least long-term effectiveness and permanence.

Reduction in Toxicity, Mobility or Volume Through Treatment - A comparison of comprehensive alternatives with respect to reductions in toxicity, mobility or volume through treatment is presented in Table 5-5. Alternative 4 is the only alternative to provide a reduction in ground water contaminant mobility through treatment. However, due to the continued presence of subsurface wastes as a potential source of ground water contamination, the permanence of any ground water toxicity reductions is not ensured should treatment be discontinued. Alternative 3 provides a reduction in contaminant mobility through its containment features. Alternatives 1 and 2 offer no reductions in contaminant toxicity, mobility or volume.

Short-Term Effectiveness - A comparison of comprehensive alternatives with respect to short-term effectiveness is presented in Table 5-6. Both Alternatives 3 and 4 may result in minor increases in on-site short-term risks due to the disruption of the site to construct containment systems. These risks could be minimized through the use of personnel protective equipment. Remedial action objectives would be achieved for both Alternatives 3 and 4. While Alternatives 1 and 2 would have no increased short-term risks associated with their implementation, they would not meet remedial action objectives.

Implementability - A comparison of comprehensive alternatives with respect to implementability is presented in Table 5-7. Alternative 1 is the most implementable alternative since it requires no remedial actions. Alternative 2 is the next most implementable alternative, requiring only long-term monitoring, fence construction and the implementation of deed restrictions. Alternative 3 follows, requiring the construction of a cap and provision of sediment containment. Alternative 4 requires the greatest construction effort, including a cap, vertical barrier system and ground water extraction, treatment and discharge systems.

Cost - A comparison of comprehensive alternatives with respect to cost is presented in Table 5-8. Costs vary widely, with the no action alternative the least costly to implement, requiring only the five-year review. Alternative 2, the limited action alternative, assumed to consist of media-specific Alternatives S/W-2 and GW-2A, is estimated have a total present worth value of $2,200,000. Alternative 3, the containment alternative, is estimated to cost in the range of $5,000,000 to $5,600,000, depending on the type of cap selected. The alternative is assumed to consist of media-specific Alternatives S/W-3A or S/W-3B combined with Alternatives SD-3 and GW-2A. The most costly alternative to implement would be Alternative 4, the containment with ground water treatment alternative. Assuming it consists of media-specific Alternatives S/W-3B, GW-2A, GW-3B, GW-4A, GW-4B, GW-4D and GW-4F, it would cost approximately $13,000,000 to implement.

5.2 Recommendations and Conclusions

Based on the evaluation presented in the previous section, the recommended remedial alternative for Site 09 consists of a containment action, as described in Section 5.1.3, consisting of the following:

- Landfill cap consisting of a native soil cap or single-barrier cap (Alternative S/W-3B, RCRA Hybrid cap)
- Containment of landfill toe sediments
- Deed restrictions to limit future exposures to subsurface waste materials, disruption of the capping system, and contaminated ground water
- Long-term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present ecological risks.

This alternative would be protective of human health and the environment, would be effective in the long-term, and would comply with location-specific and action-specific ARARs. Based on the lack of ecological impacts attributable to contaminated ground water migration identified during site and Allen Harbor ecological studies, the lack of ground water treatment is not expected to adversely effect the environment. Long-term monitoring would be utilized to ensure continued protection of the environment. Protection against human health and ecological risks posed by surficial contamination, leachate seeps, and sediment contamination at the toe of the landfill would be provided by the containment features of the alternative. Deed restrictions would limit the potential for future disruption of the containment systems. The alternative would complement future use of the site for recreation or conservation purposes, as specified in the Base Reuse Plan.

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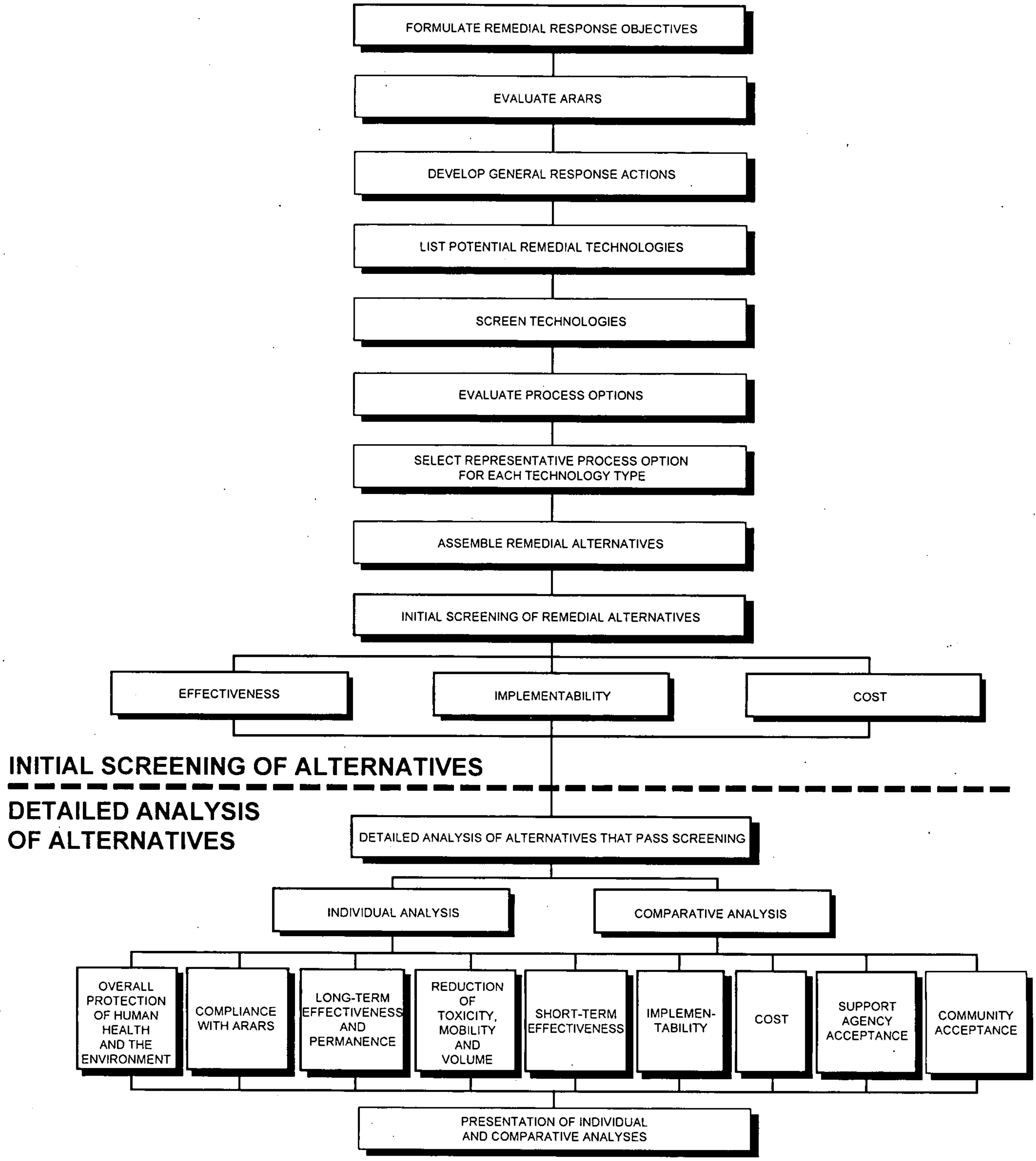

SOURCE: USEPA

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FIGURE 1-1.

FEASIBILITY STUDY APPROACH

Date: 3/94 | Project No. 01042-0040

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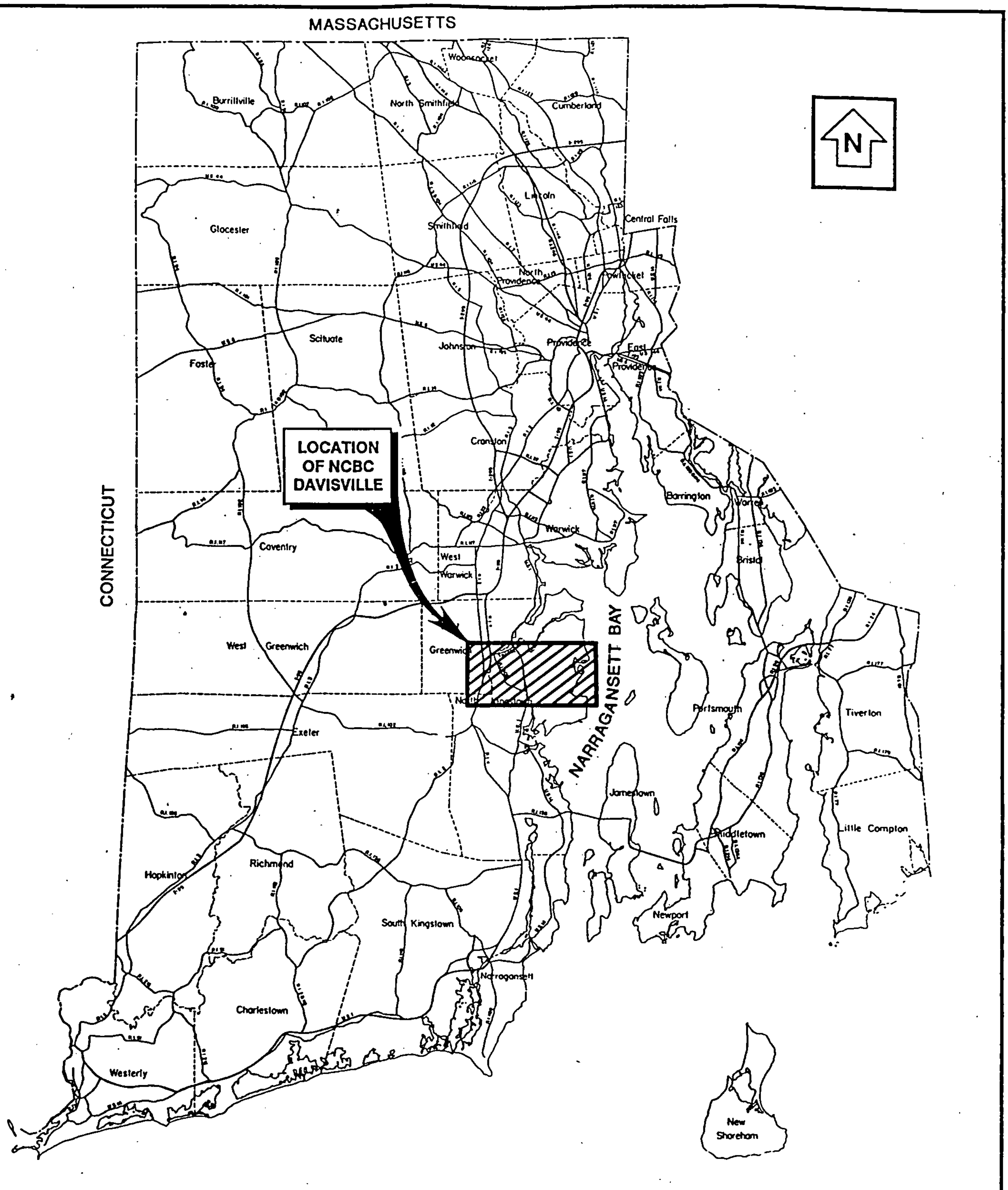

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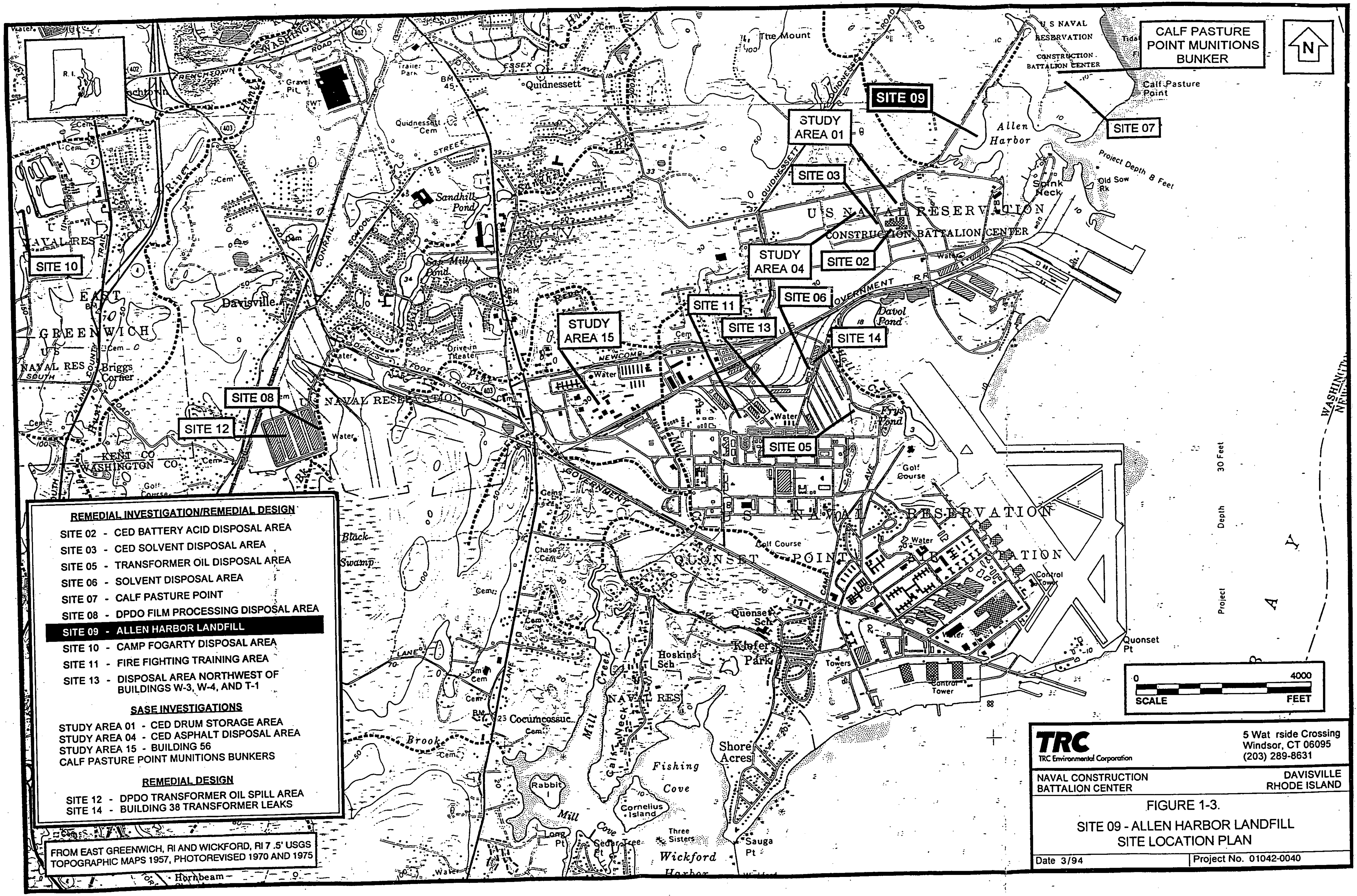
FIGURE 1-2.

NCBC SITE LOCATION PLAN

Date 3/94 | Project No. 01042-0040



CALF PASTURE POINT MUNITIONS BUNKER
N
SITE 09
STUDY AREA 01
SITE 07
SITE 03
STUDY AREA 04
SITE 02
SITE 10
SITE 11
SITE 06
SITE 13
SITE 14
STUDY AREA 15
SITE 08
SITE 12
SITE 05
U S NAVAL RESERVATION
CONSTRUCTION BATTALION CENTER
QUONSET POINT NAVAL AIR STATION
Allen Harbor
Calf Pasture Point
Quidnessett
Davisville
EAST GREENWICH
Sandhill Pond
Davol Pond
Frys Pond
Black Swamp
Fishing Cove
Cornelius Island
Rabbit I
Wickford Harbor
Quonset Pt
Project Depth 8 Feet
Project Depth 30 Feet
REMEDIAL INVESTIGATION/REMEDIAL DESIGN
SITE 02 - CED BATTERY ACID DISPOSAL AREA
SITE 03 - CED SOLVENT DISPOSAL AREA
SITE 05 - TRANSFORMER OIL DISPOSAL AREA
SITE 06 - SOLVENT DISPOSAL AREA
SITE 07 - CALF PASTURE POINT
SITE 08 - DPDO FILM PROCESSING DISPOSAL AREA
SITE 09 - ALLEN HARBOR LANDFILL
SITE 10 - CAMP FOGARTY DISPOSAL AREA
SITE 11 - FIRE FIGHTING TRAINING AREA
SITE 13 - DISPOSAL AREA NORTHWEST OF BUILDINGS W-3, W-4, AND T-1
SASE INVESTIGATIONS
STUDY AREA 01 - CED DRUM STORAGE AREA
STUDY AREA 04 - CED ASPHALT DISPOSAL AREA
STUDY AREA 15 - BUILDING 56
CALF PASTURE POINT MUNITIONS BUNKERS
REMEDIAL DESIGN
SITE 12 - DPDO TRANSFORMER OIL SPILL AREA
SITE 14 - BUILDING 38 TRANSFORMER LEAKS
FROM EAST GREENWICH, RI AND WICKFORD, RI 7 .5' USGS TOPOGRAPHIC MAPS 1957, PHOTOREVISED 1970 AND 1975
0 4000
SCALE FEET
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FIGURE 1-3.
SITE 09 - ALLEN HARBOR LANDFILL
SITE LOCATION PLAN
Date 3/94
Project No. 01042-0040

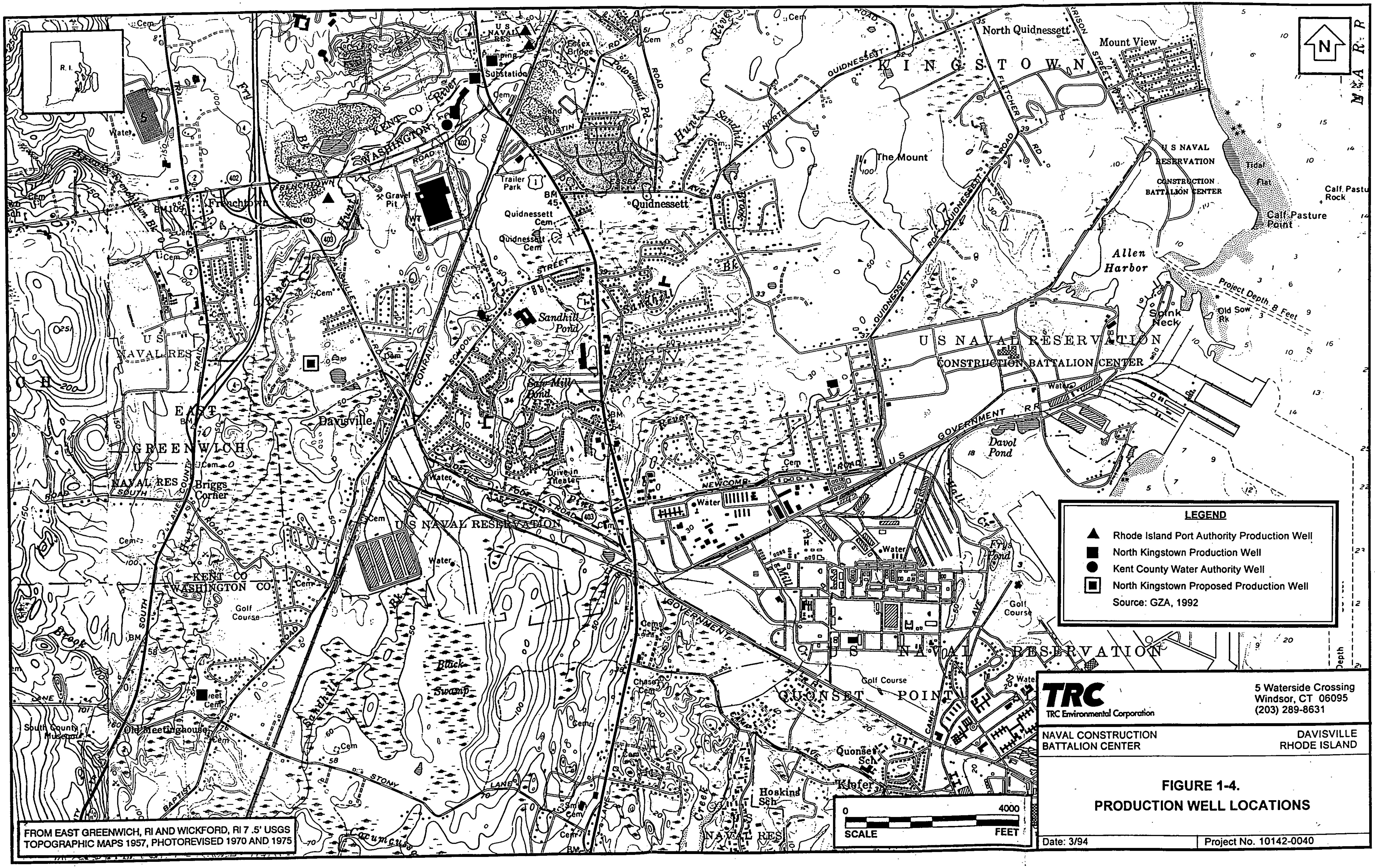

FIGURE 1-4.
PRODUCTION WELL LOCATIONS

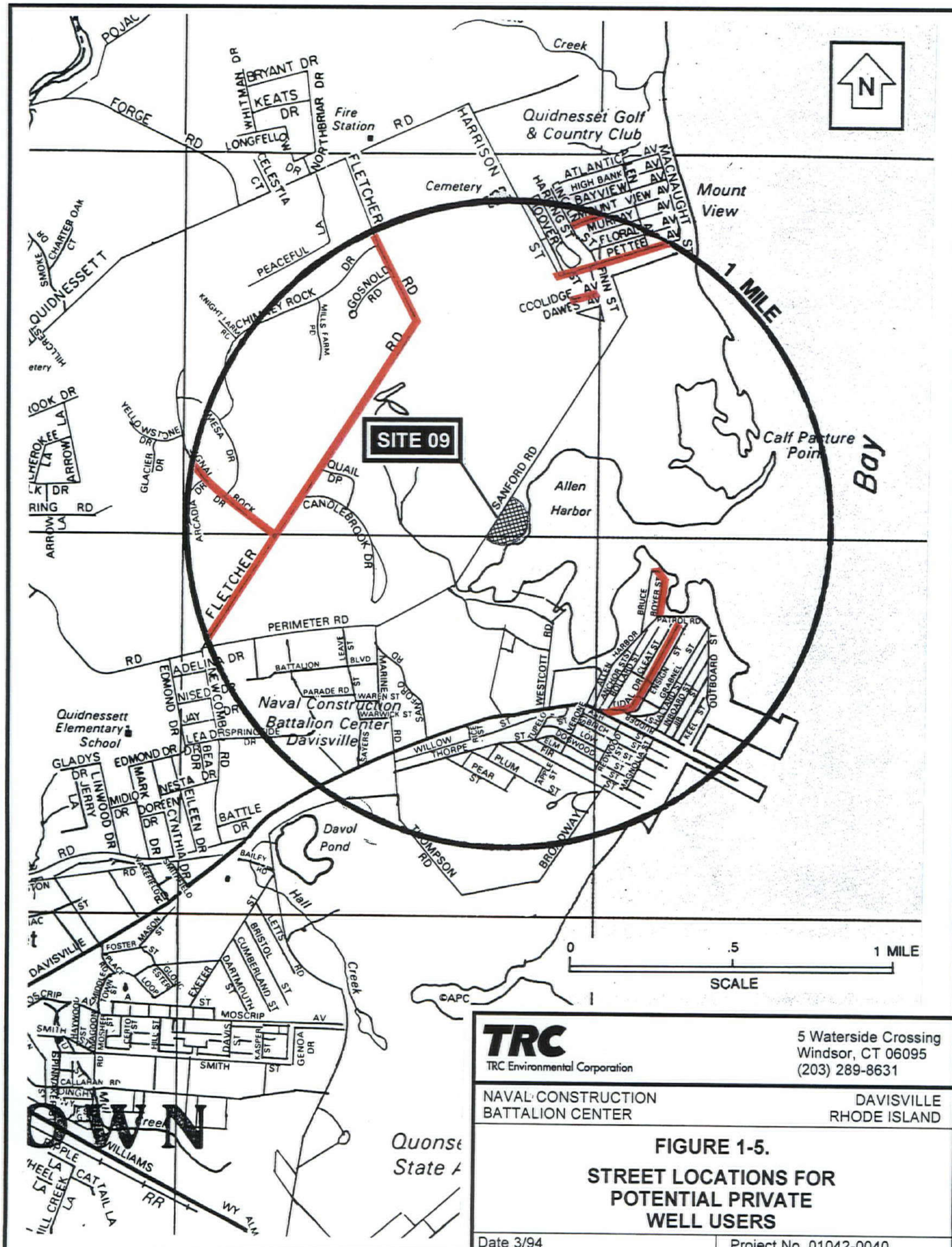

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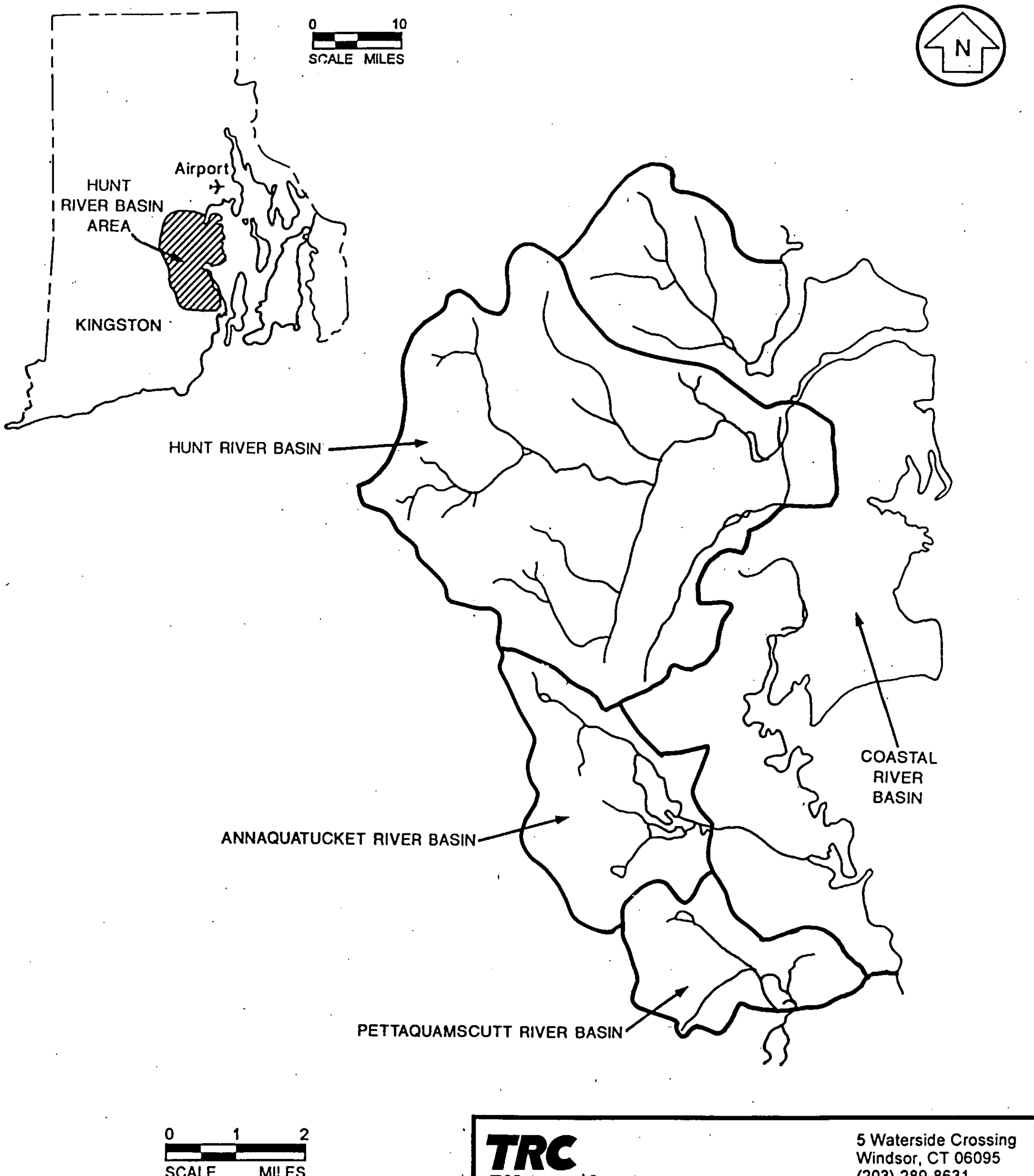
FIGURE 1-5.

STREET LOCATIONS FOR POTENTIAL PRIVATE WELL USERS

Date 3/94 — Project No. 01042-0040



LEGEND

BASIN BOUNDARY

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FIGURE 1-6.

HUNT RIVER DRAINAGE BASIN

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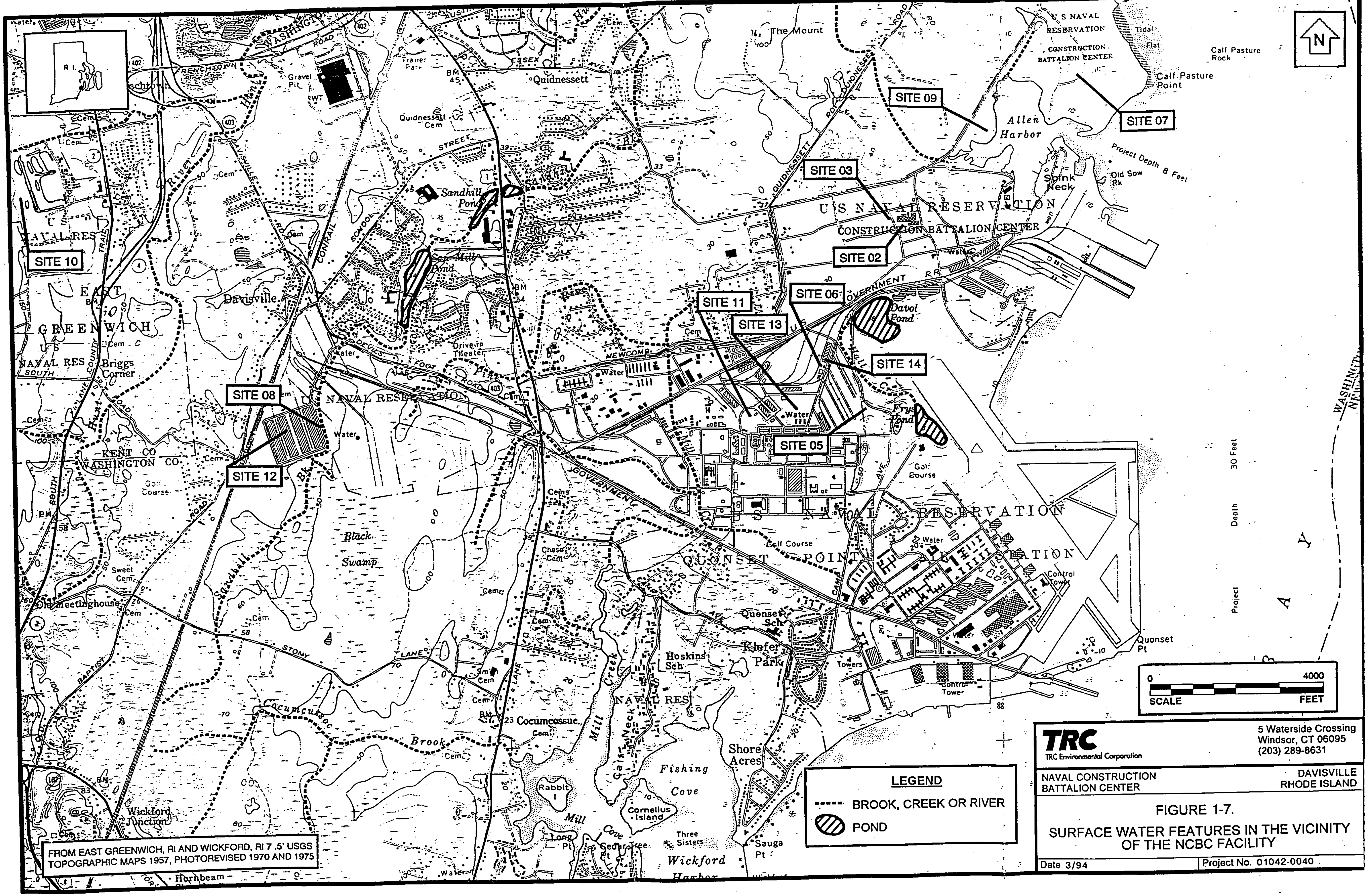


FIGURE 1-7.

SURFACE WATER FEATURES IN THE VICINITY OF THE NCBC FACILITY

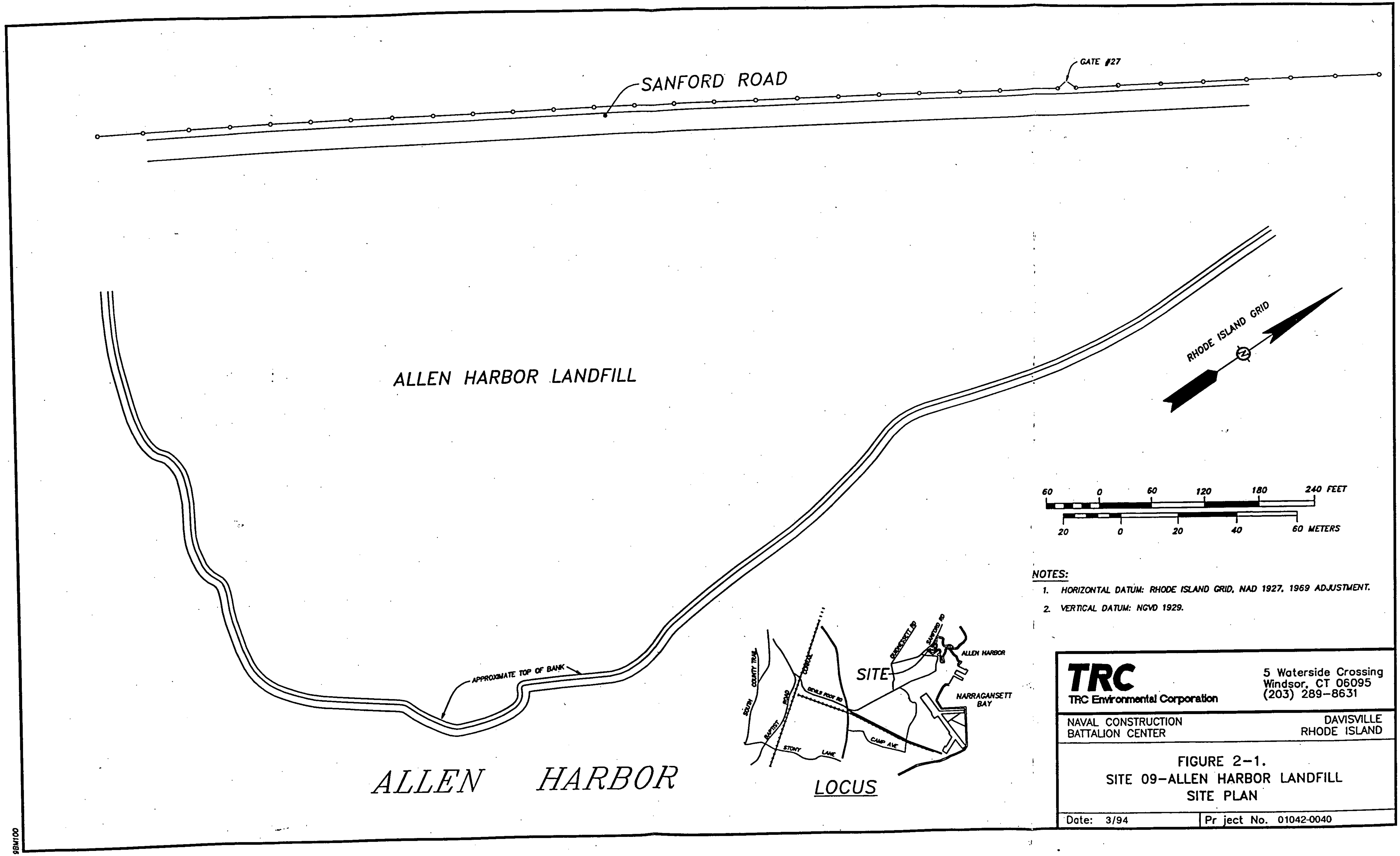
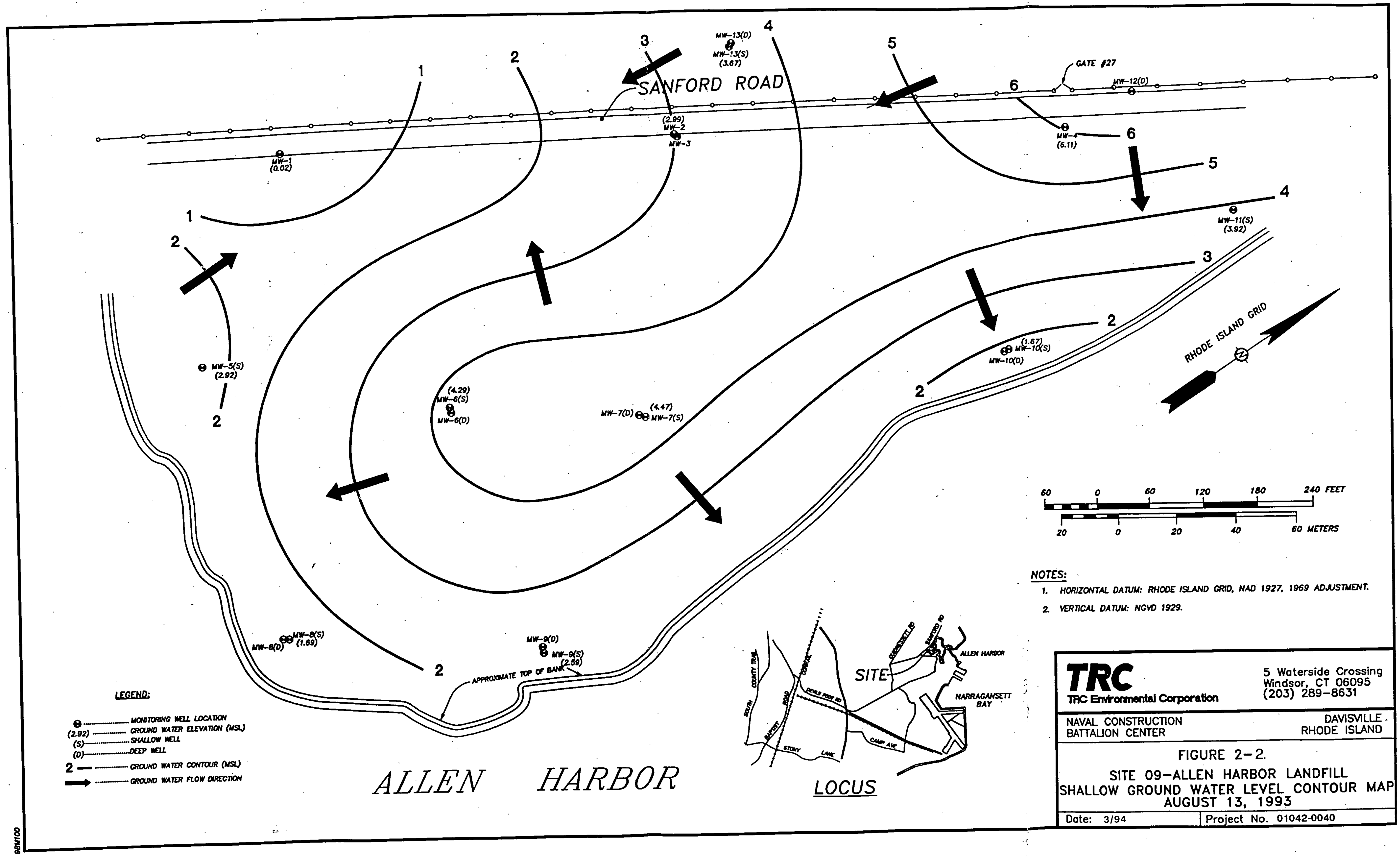


FIGURE 2-1.
SITE 09-ALLEN HARBOR LANDFILL
SITE PLAN

9BM100



NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

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FIGURE 2-2.
SITE 09-ALLEN HARBOR LANDFILL
SHALLOW GROUND WATER LEVEL CONTOUR MAP
AUGUST 13, 1993

Date: 3/94 | Project No. 01042-0040

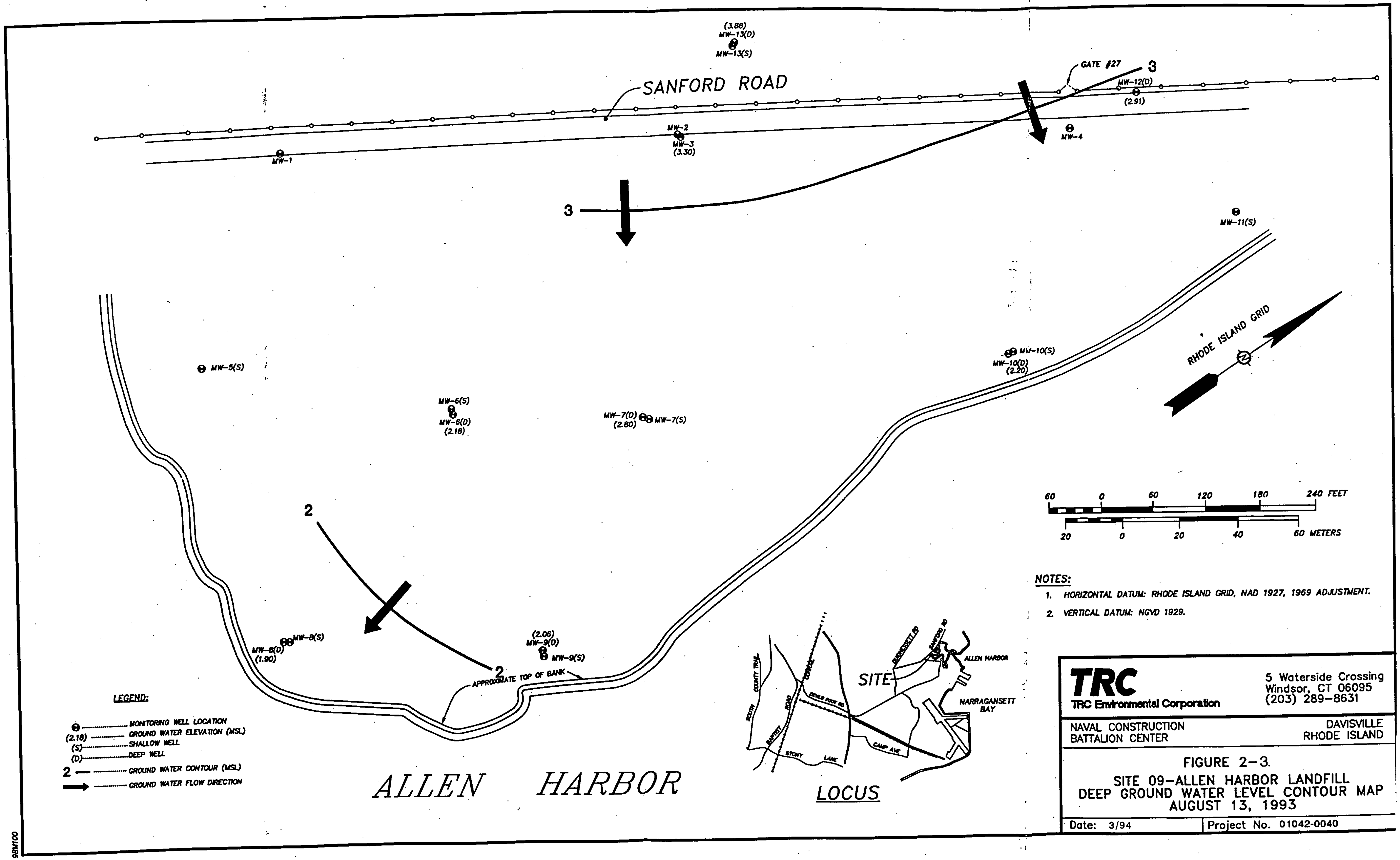


FIGURE 2-3.
SITE 09-ALLEN HARBOR LANDFILL
DEEP GROUND WATER LEVEL CONTOUR MAP
AUGUST 13, 1993

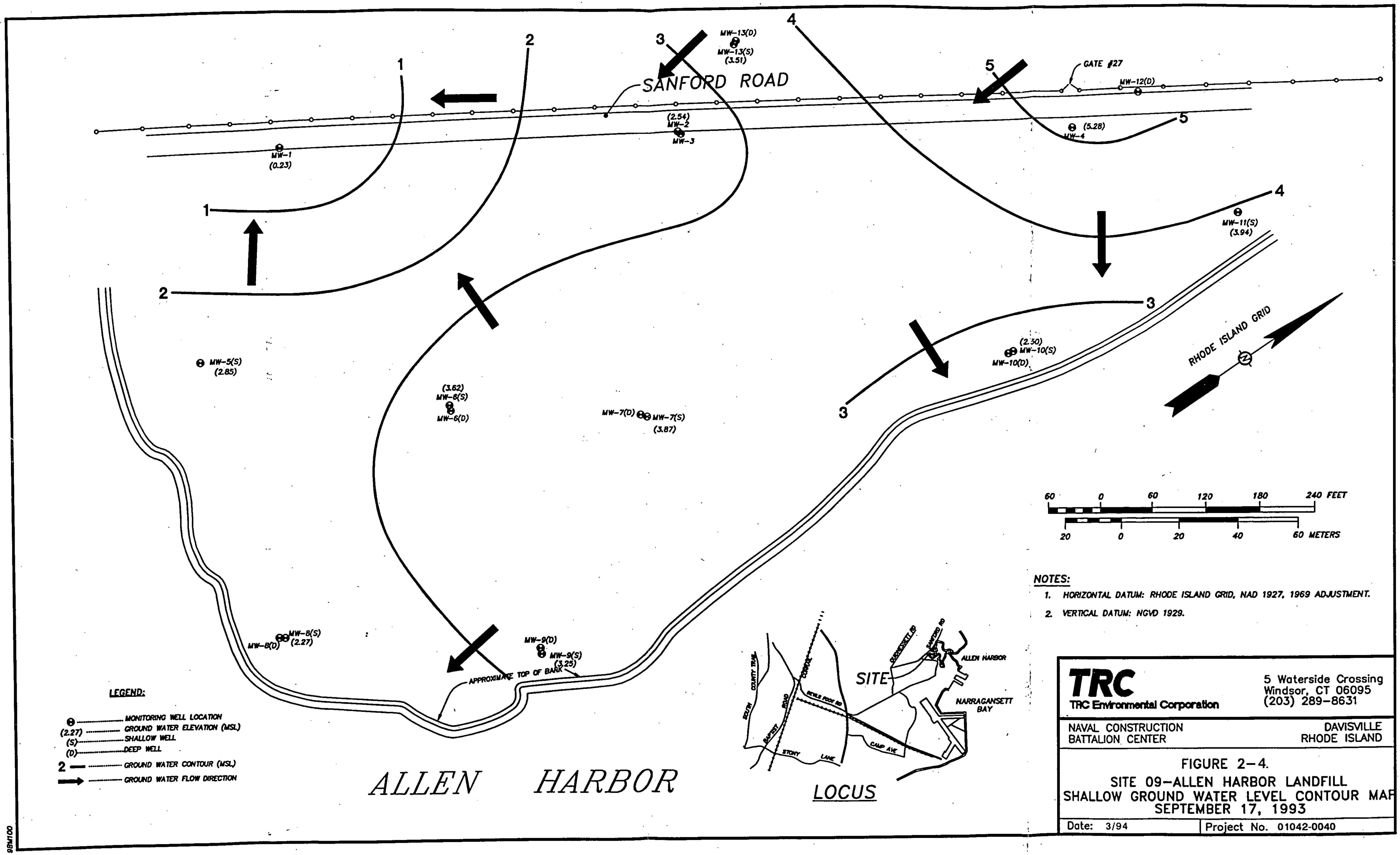
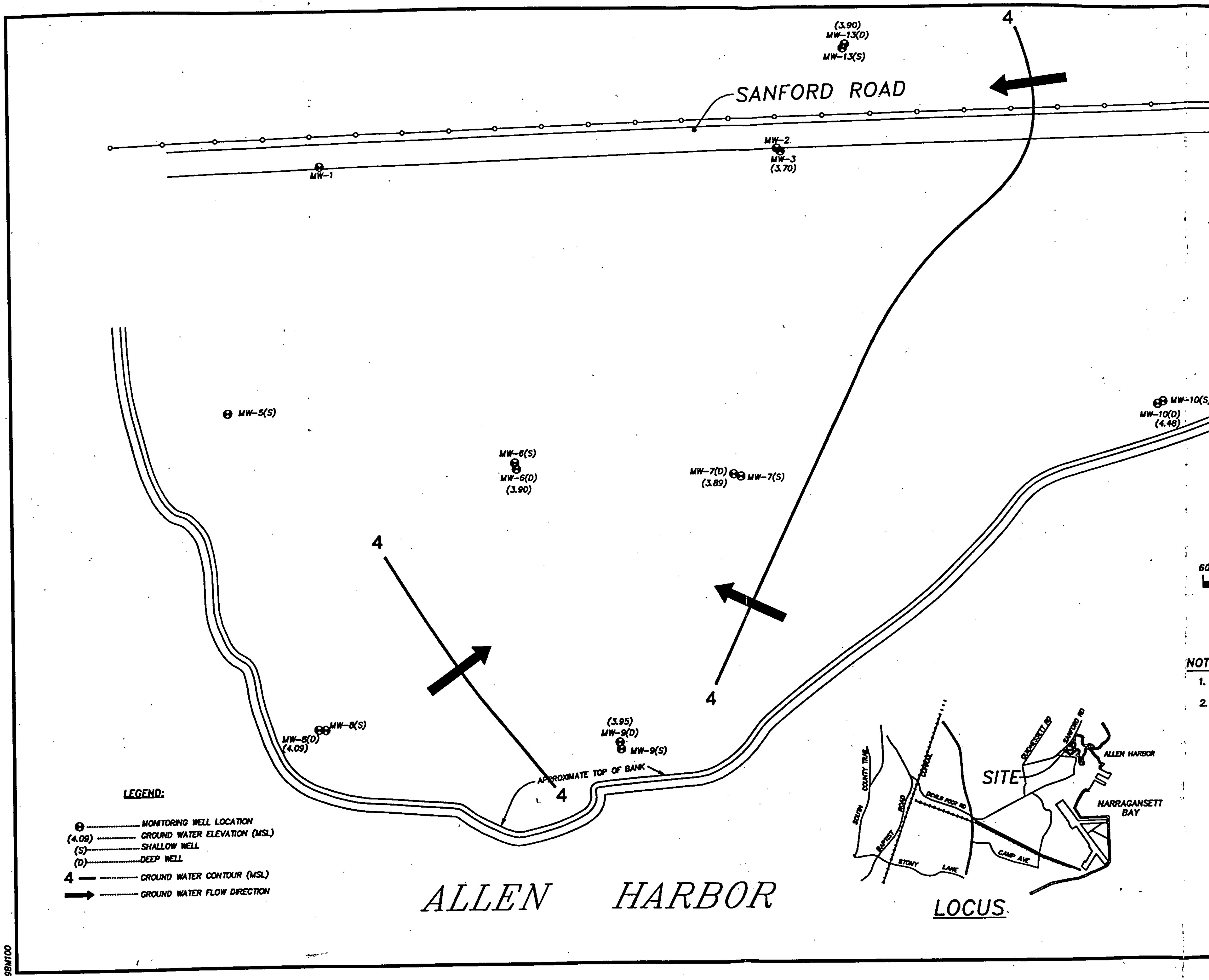


FIGURE 2-4.
SITE 09-ALLEN HARBOR LANDFILL
SHALLOW GROUND WATER LEVEL CONTOUR MAP
SEPTEMBER 17, 1993



NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

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FIGURE 2-5.
SITE 09-ALLEN HARBOR LANDFILL
DEEP GROUND WATER LEVEL CONTOUR MAP
SEPTEMBER 17, 1993

Date: 3/94 | Pr ject No. 01042-0040

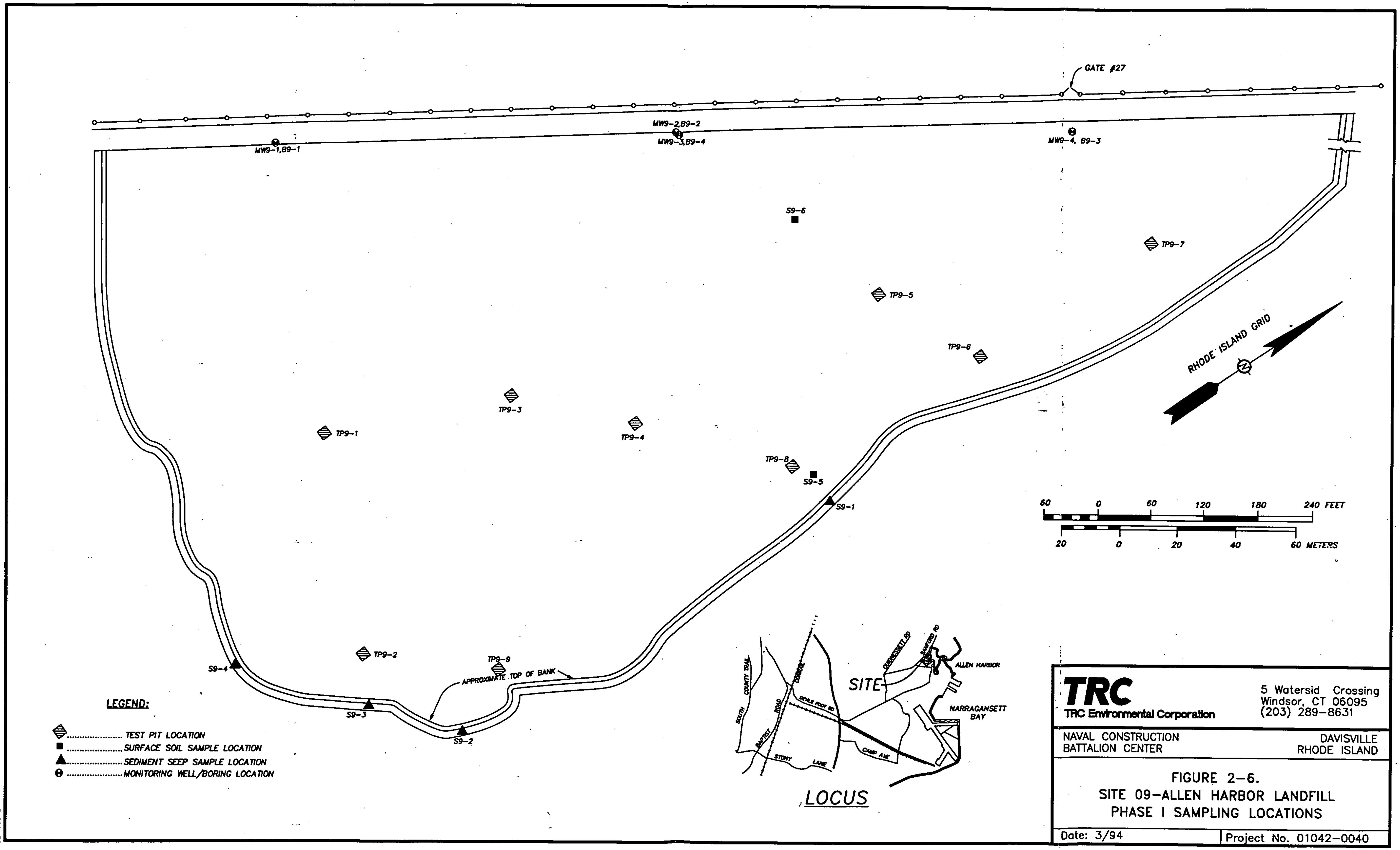

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FIGURE 2-6.
SITE 09-ALLEN HARBOR LANDFILL
PHASE I SAMPLING LOCATIONS

Date: 3/94
Project No. 01042-0040

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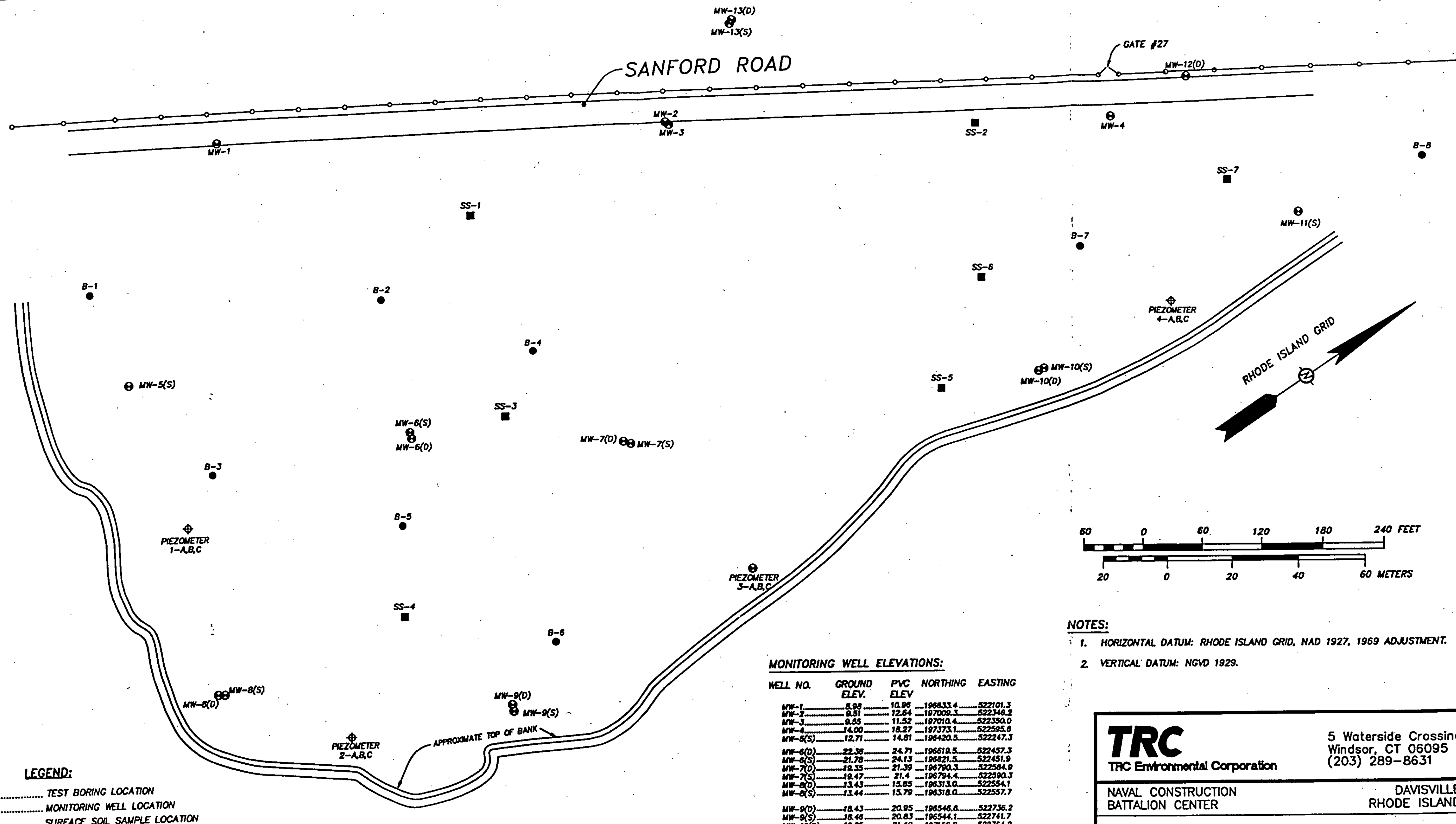

MONITORING WELL ELEVATIONS:

WELL NO.	GROUND ELEV.	PVC ELEV	NORTHING	EASTING
MW-1	5.98	10.96	196833.4	522101.3
MW-2	8.51	12.64	197009.3	522346.2
MW-3	9.55	11.52	197010.4	522350.0
MW-4	14.00	18.27	197373.1	522595.6
MW-5(S)	12.71	14.81	196420.5	522247.3
MW-6(D)	22.36	24.71	196619.5	522457.3
MW-6(S)	21.78	24.13	196621.5	522451.9
MW-7(D)	19.35	21.39	196790.3	522584.9
MW-7(S)	19.47	21.4	196794.4	522590.3
MW-8(D)	13.43	15.85	196313.0	522554.1
MW-8(S)	13.44	15.79	196318.0	522557.7
MW-9(D)	18.43	20.95	196546.6	522736.2
MW-9(S)	18.46	20.83	196544.1	522741.7
MW-10(D)	19.25	21.49	197166.8	522764.2
MW-10(S)	18.80	21.37	197172.1	522765.2
MW-11(S)	12.35	14.63	197471.4	522783.0
MW-12(D)	13.53	13.10	197457.5	522609.8
MW-13(D)	6.47	9.28	197121.5	522298.9
MW-13(S)	6.31	8.84	197117.8	522300.7

LEGEND:

- ● .... TEST BORING LOCATION
- ⊖ .... MONITORING WELL LOCATION
- ■ .... SURFACE SOIL SAMPLE LOCATION
- (S) .... SHALLOW WELL
- (D) .... DEEP WELL
- ⊕ .... MULTI-LEVEL PIEZOMETER

NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

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FIGURE 2-7.
SITE 09-ALLEN HARBOR LANDFILL
PHASE II SAMPLING LOCATIONS

Date: 3/94 | Project No. 01042-0040

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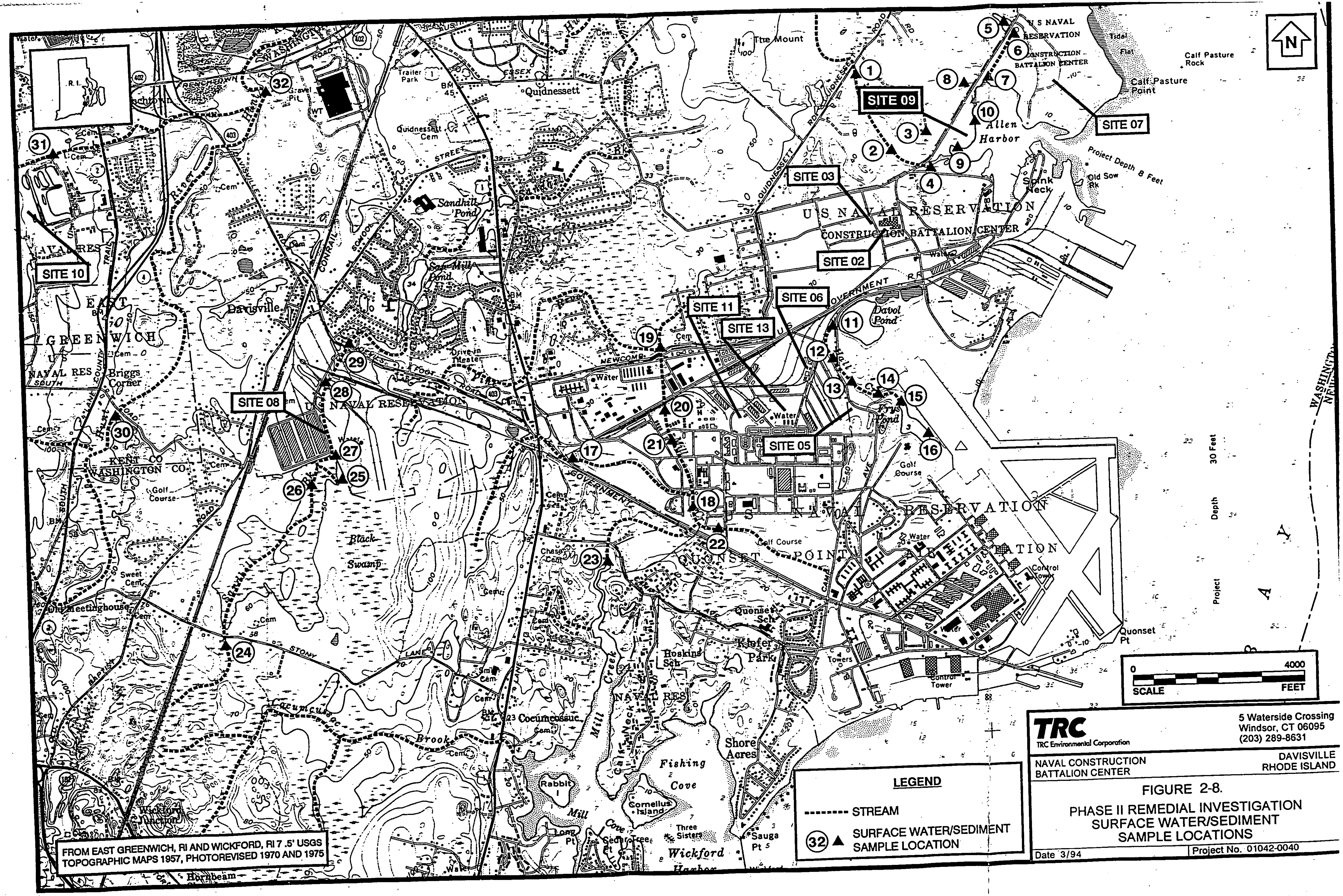

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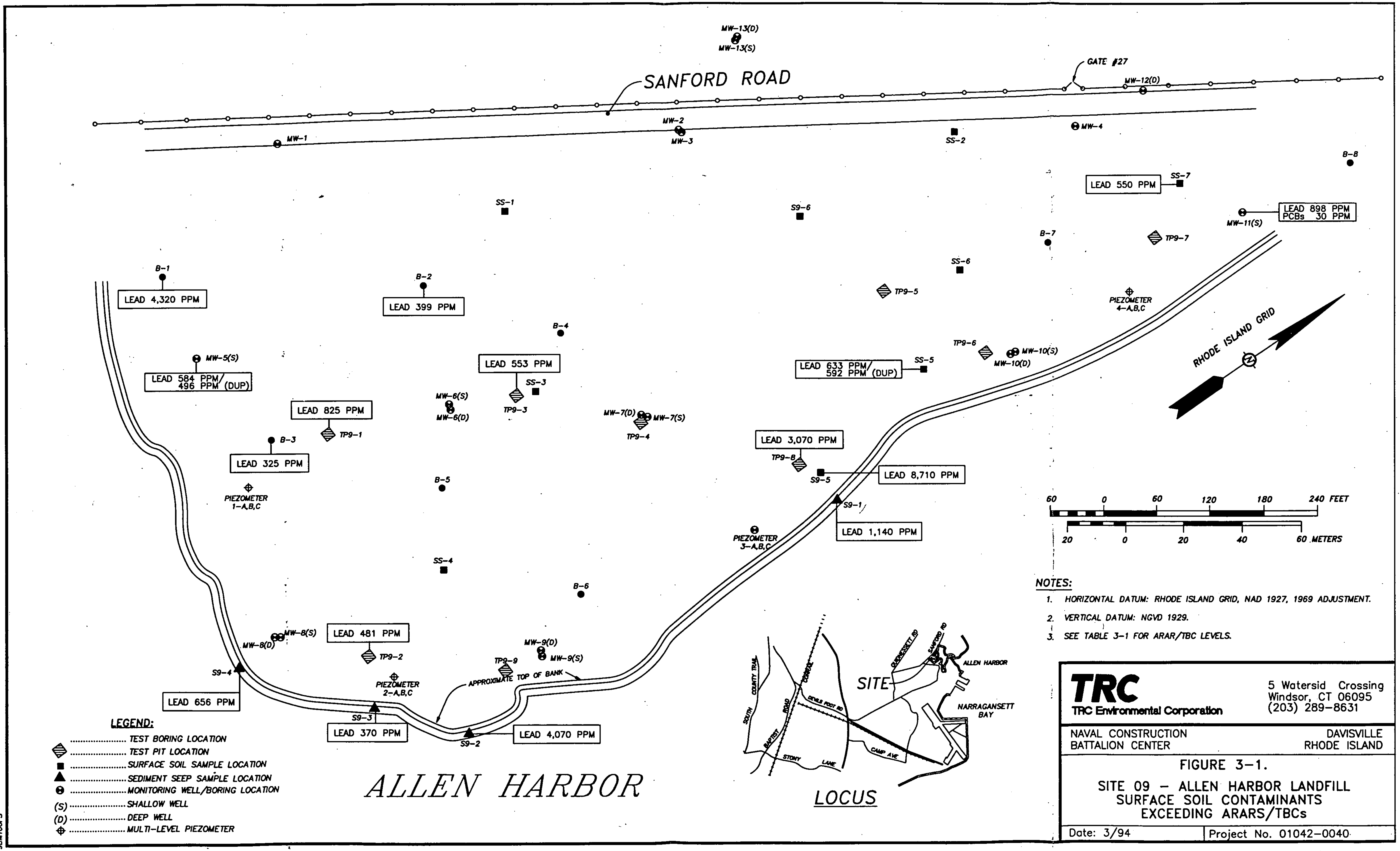
FIGURE 2-8.
PHASE II REMEDIAL INVESTIGATION
SURFACE WATER/SEDIMENT
SAMPLE LOCATIONS

Date 3/94
Project No. 01042-0040



SANFORD ROAD
GATE #27
MW-13(D)
MW-13(S)
MW-12(D)
MW-1
MW-2
MW-3
SS-2
MW-4
B-8
LEAD 550 PPM
SS-7
LEAD 898 PPM
PCBs 30 PPM
MW-11(S)
SS-1
S9-6
B-7
TP9-7
SS-6
TP9-5
PIEZOMETER
4-A,B,C
B-1
LEAD 4,320 PPM
B-2
LEAD 399 PPM
B-4
TP9-6
MW-10(S)
MW-10(D)
LEAD 633 PPM/
592 PPM (DUP)
SS-5
MW-5(S)
LEAD 584 PPM/
496 PPM (DUP)
LEAD 553 PPM
SS-3
TP9-3
MW-6(S)
MW-6(D)
LEAD 825 PPM
TP9-1
MW-7(D)
MW-7(S)
TP9-4
LEAD 3,070 PPM
TP9-8
S9-5
LEAD 8,710 PPM
B-3
LEAD 325 PPM
B-5
PIEZOMETER
1-A,B,C
S9-1
LEAD 1,140 PPM
PIEZOMETER
3-A,B,C
SS-4
B-6
RHODE ISLAND GRID
N
60 0 60 120 180 240 FEET
20 0 20 40 60 METERS
NOTES:
1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.
3. SEE TABLE 3-1 FOR ARAR/TBC LEVELS.
MW-8(S)
MW-8(D)
LEAD 481 PPM
TP9-2
MW-9(D)
MW-9(S)
TP9-9
S9-4
PIEZOMETER
2-A,B,C
APPROXIMATE TOP OF BANK
LEAD 656 PPM
S9-3
LEAD 370 PPM
S9-2
LEAD 4,070 PPM
LEGEND:
TEST BORING LOCATION
TEST PIT LOCATION
SURFACE SOIL SAMPLE LOCATION
SEDIMENT SEEP SAMPLE LOCATION
MONITORING WELL/BORING LOCATION
(S) SHALLOW WELL
(D) DEEP WELL
MULTI-LEVEL PIEZOMETER
ALLEN HARBOR
SITE
ALLEN HARBOR
NARRAGANSETT BAY
SOUTH COUNTY TRAIL
BAPTIST ROAD
DEVILS FOOT RD
STONY LANE
CAMP AVE
LOCUS
TRC
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DAVISVILLE RHODE ISLAND
FIGURE 3-1.
SITE 09 - ALLEN HARBOR LANDFILL
SURFACE SOIL CONTAMINANTS
EXCEEDING ARARS/TBCs
Date: 3/94
Project No. 01042-0040

98M100FS

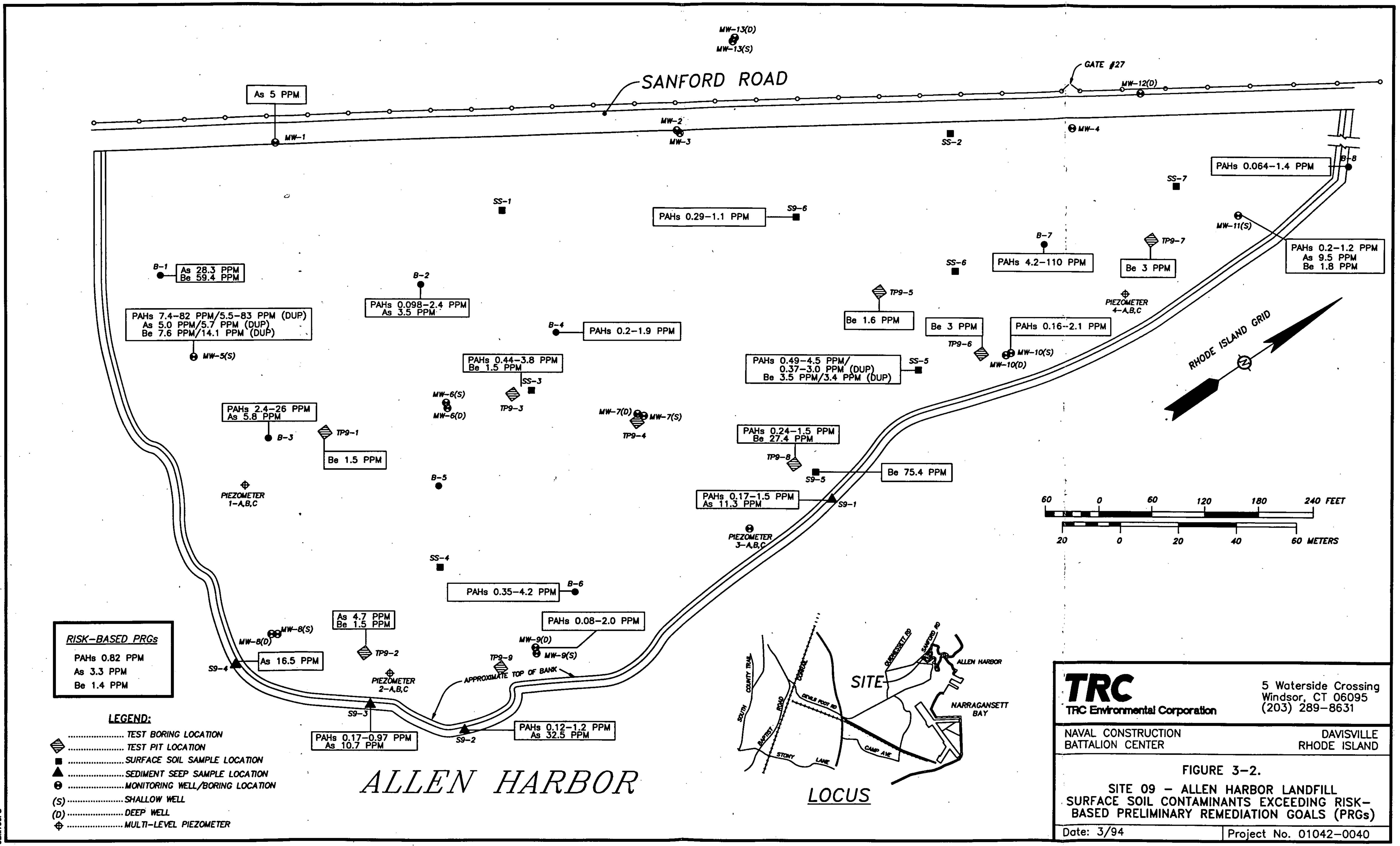
SANFORD ROAD
GATE #27
MW-13(D)
MW-13(S)
MW-12(D)
As 5 PPM
MW-1
MW-2
MW-3
SS-2
MW-4
PAHs 0.064-1.4 PPM
B-8
SS-7
SS-1
PAHs 0.29-1.1 PPM
S9-6
MW-11(S)
PAHs 0.2-1.2 PPM
As 9.5 PPM
Be 1.8 PPM
B-7
PAHs 4.2-110 PPM
TP9-7
Be 3 PPM
SS-6
B-1
As 28.3 PPM
Be 59.4 PPM
B-2
PAHs 0.098-2.4 PPM
As 3.5 PPM
TP9-5
Be 1.6 PPM
Be 3 PPM
PAHs 0.16-2.1 PPM
PIEZOMETER 4-A,B,C
PAHs 7.4-82 PPM/5.5-83 PPM (DUP)
As 5.0 PPM/5.7 PPM (DUP)
Be 7.6 PPM/14.1 PPM (DUP)
B-4
PAHs 0.2-1.9 PPM
TP9-6
MW-10(S)
MW-10(D)
RHODE ISLAND GRID
MW-5(S)
PAHs 0.44-3.8 PPM
Be 1.5 PPM
SS-3
PAHs 0.49-4.5 PPM/
0.37-3.0 PPM (DUP)
Be 3.5 PPM/3.4 PPM (DUP)
SS-5
MW-6(S)
MW-6(D)
TP9-3
MW-7(D)
MW-7(S)
TP9-4
PAHs 2.4-26 PPM
As 5.8 PPM
B-3
TP9-1
Be 1.5 PPM
PAHs 0.24-1.5 PPM
Be 27.4 PPM
TP9-8
S9-5
Be 75.4 PPM
B-5
PIEZOMETER 1-A,B,C
PAHs 0.17-1.5 PPM
As 11.3 PPM
S9-1
PIEZOMETER 3-A,B,C
60 0 60 120 180 240 FEET
20 0 20 40 60 METERS
SS-4
PAHs 0.35-4.2 PPM
B-6
As 4.7 PPM
Be 1.5 PPM
PAHs 0.08-2.0 PPM
MW-8(S)
MW-8(D)
MW-9(D)
MW-9(S)
S9-4
As 16.5 PPM
TP9-2
TP9-9
APPROXIMATE TOP OF BANK
PIEZOMETER 2-A,B,C
S9-3
S9-2
PAHs 0.17-0.97 PPM
As 10.7 PPM
PAHs 0.12-1.2 PPM
As 32.5 PPM
RISK-BASED PRGs
PAHs 0.82 PPM
As 3.3 PPM
Be 1.4 PPM
LEGEND:
TEST BORING LOCATION
TEST PIT LOCATION
SURFACE SOIL SAMPLE LOCATION
SEDIMENT SEEP SAMPLE LOCATION
MONITORING WELL/BORING LOCATION
(S) SHALLOW WELL
(D) DEEP WELL
MULTI-LEVEL PIEZOMETER
ALLEN HARBOR
SITE
ALLEN HARBOR
NARRAGANSETT BAY
SOUTH COUNTY TRAIL
CAMP AVE
STONY LANE
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FIGURE 3-2.
SITE 09 - ALLEN HARBOR LANDFILL
SURFACE SOIL CONTAMINANTS EXCEEDING RISK-BASED PRELIMINARY REMEDIATION GOALS (PRGs)
Date: 3/94
Project No. 01042-0040

9BM100FS

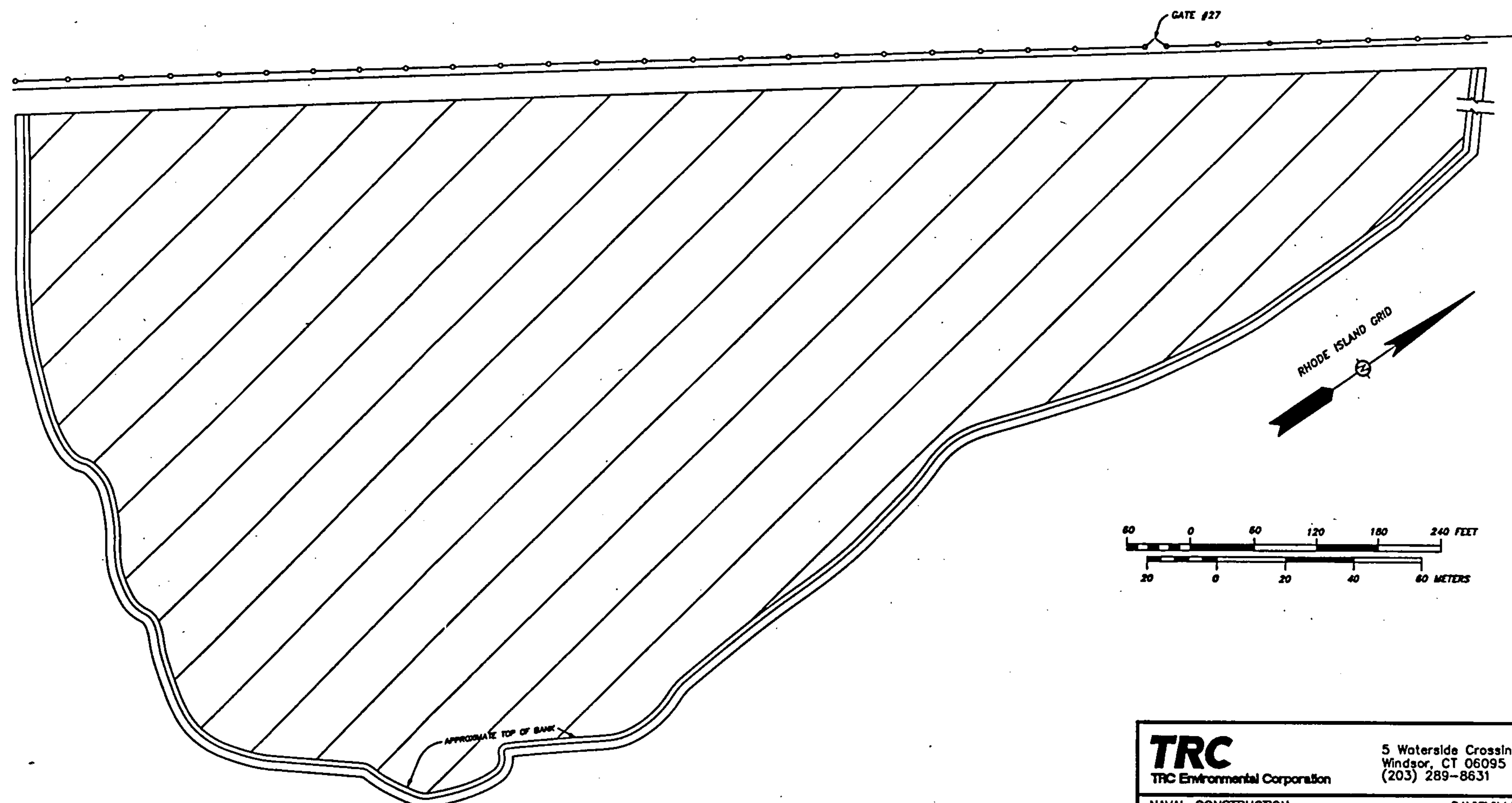

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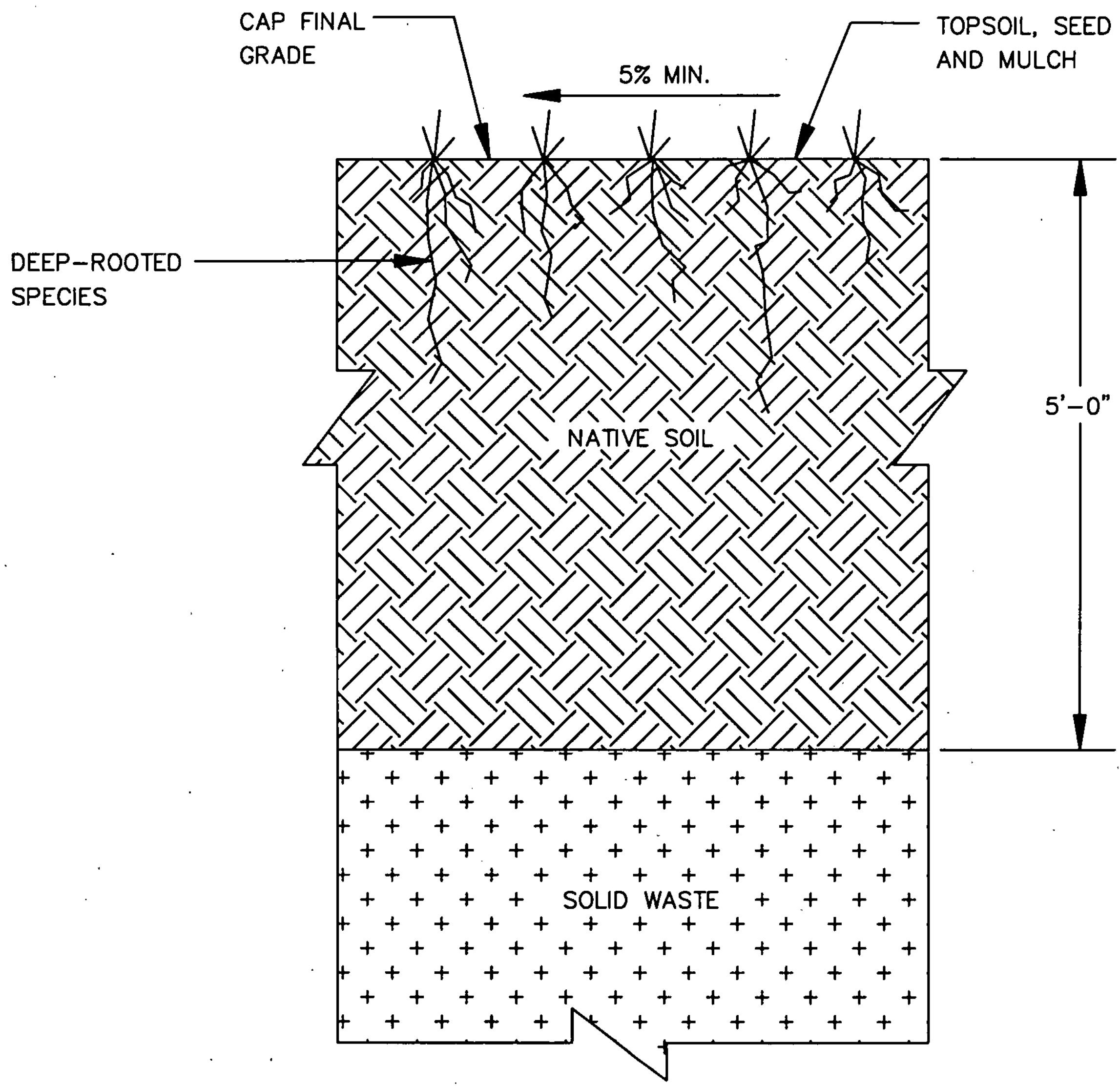
FIGURE 4-1.
SITE 09 - ALLEN HARBOR LANDFILL
EXTENT OF CAP

Date: 3/94 | Project No. 01042-0040



NOT TO SCALE

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FIGURE 4-2.
SITE 09-ALLEN HARBOR LANDFILL
NATIVE SOIL CAP CROSS-SECTION

Date: 3/94 | Project No. 01042-0040

9NATIVE

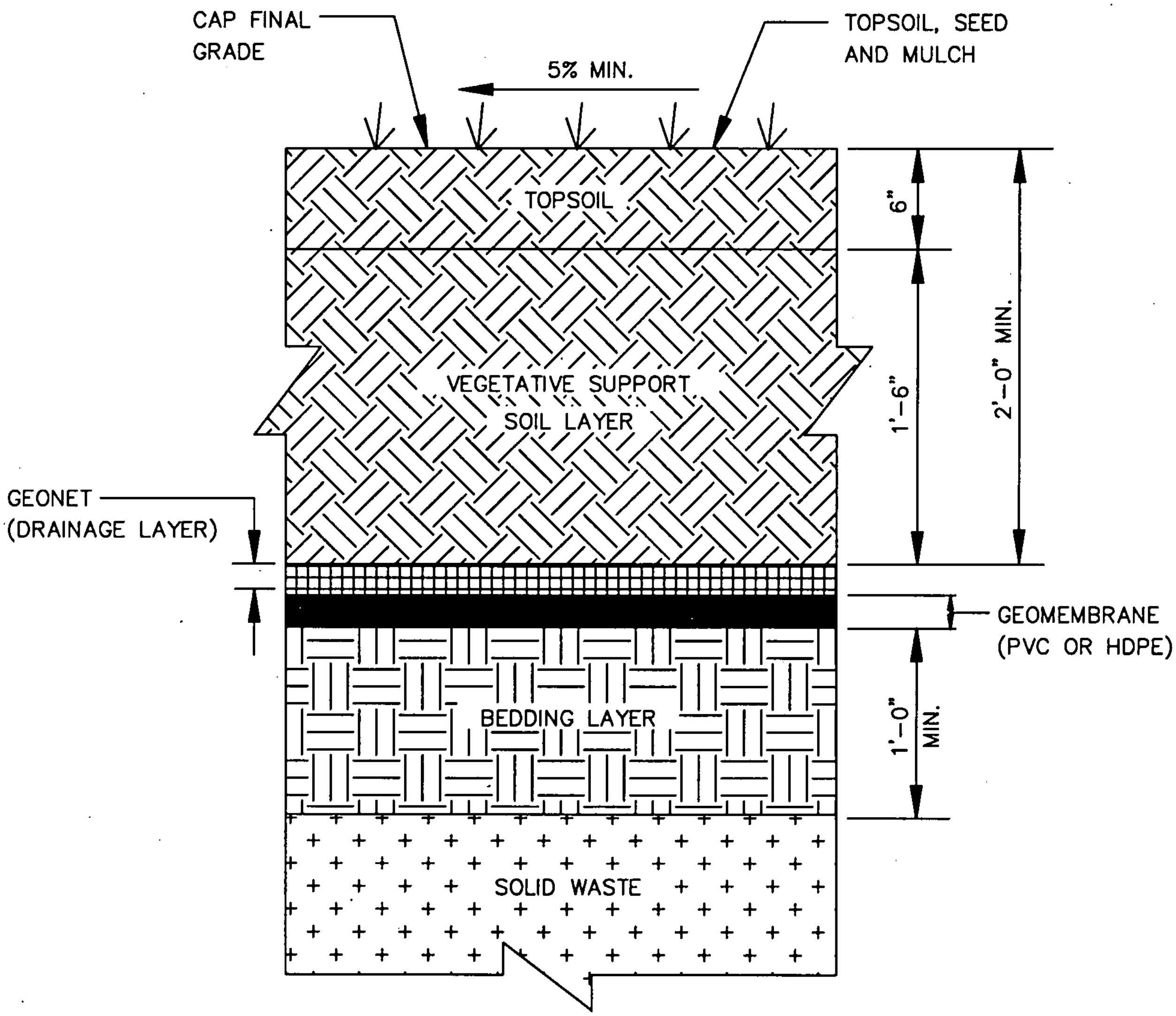

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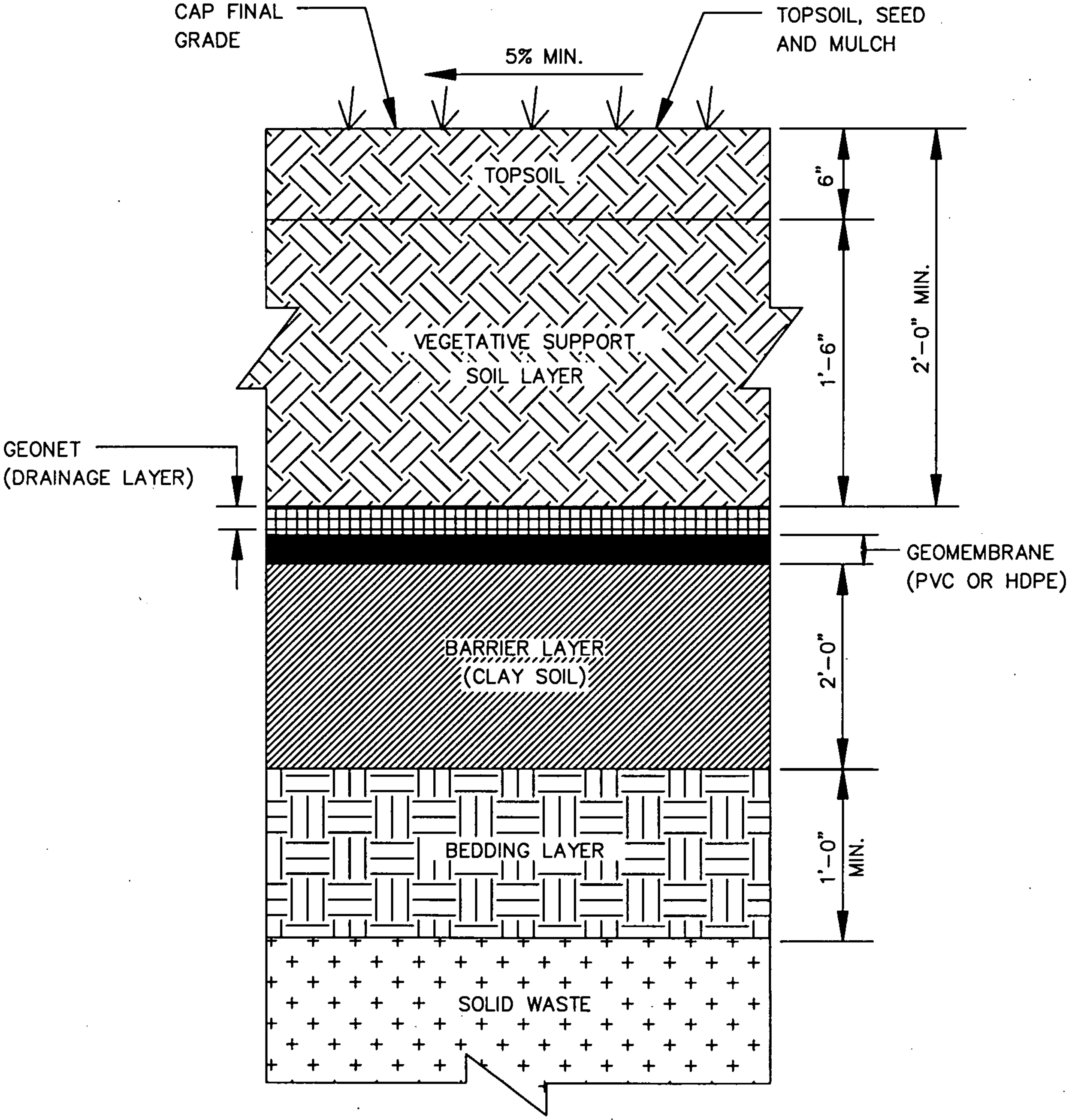
FIGURE 4-3.
SITE 09-ALLEN HARBOR LANDFILL
RCRA SUBTITLE C
HYBRID CAP CROSS-SECTION

Date: 3/94
Project No. 01042-0040

9HYBRID



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NAVAL CONSTRUCTION BATTALION CENTER — DAVISVILLE RHODE ISLAND

FIGURE 4-4.
SITE 09-ALLEN HARBOR LANDFILL
RCRA SUBTITLE C
LANDFILL CAP CROSS-SECTION

Date: 3/94 | Project No. 01042-0040

9LANDFIL

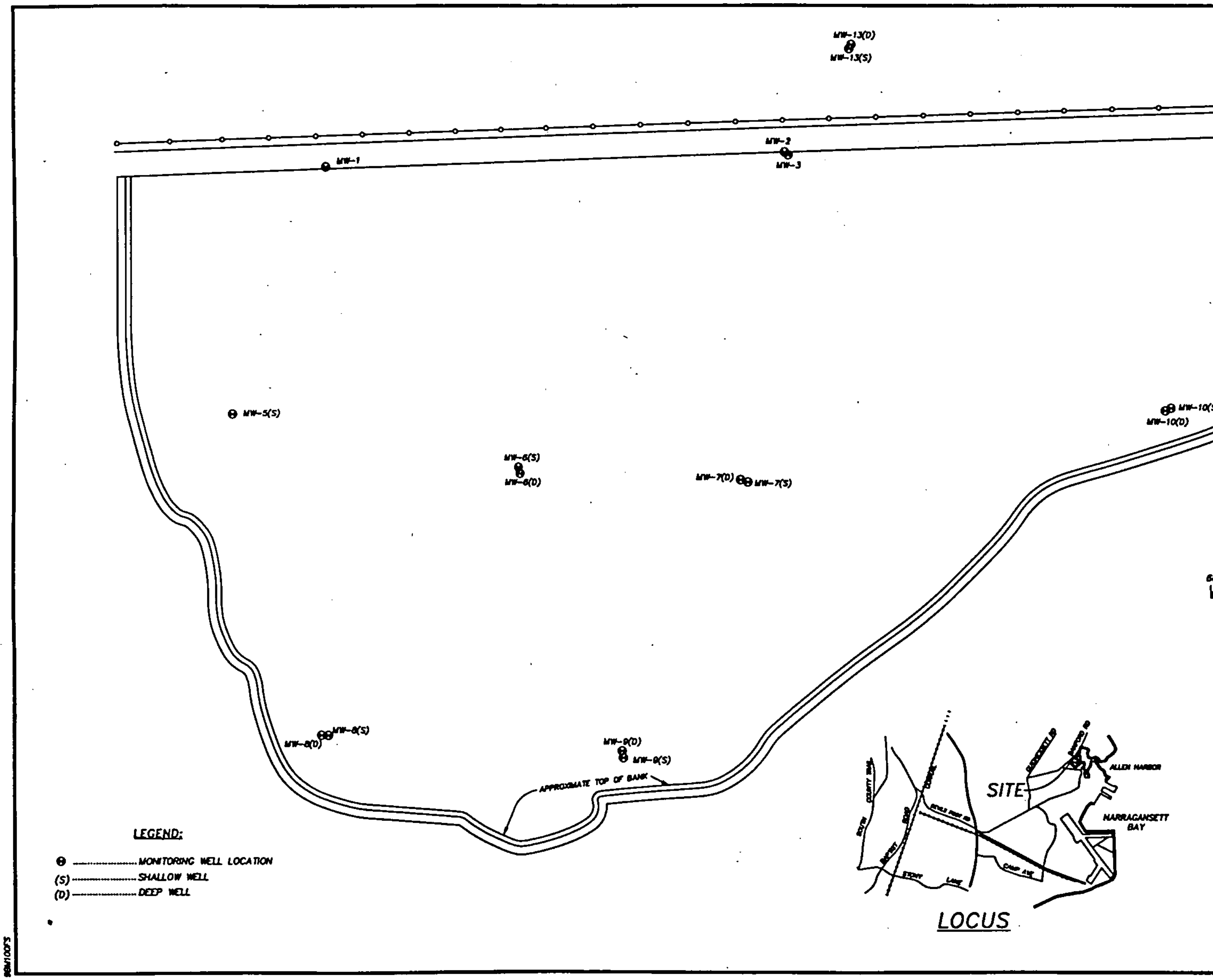

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FIGURE 4-5.
SITE 09 – ALLEN HARBOR LANDFILL
WELL LOCATIONS–
LONG-TERM MONITORING

Date: 3/94 | Project No. 01042-0040

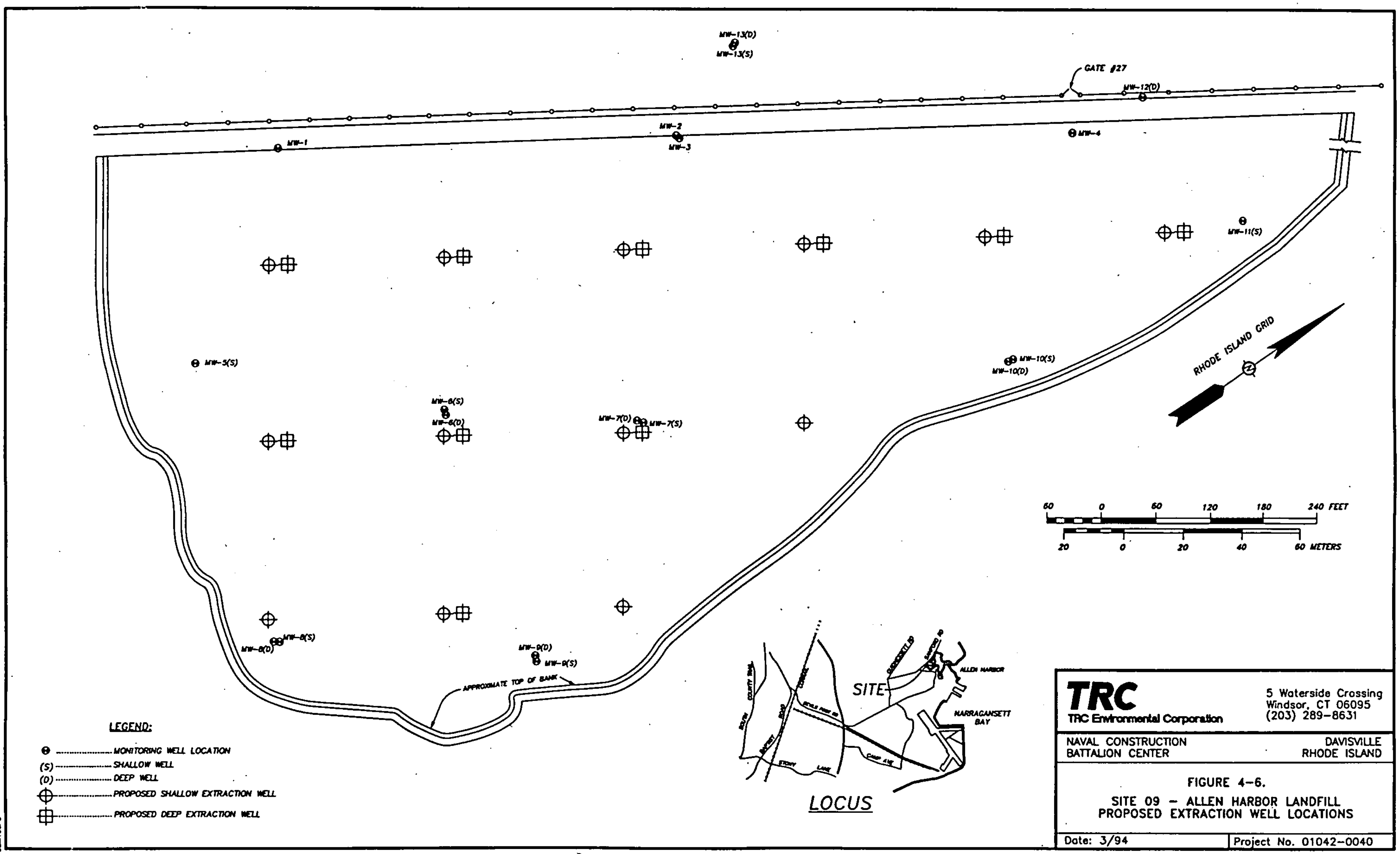

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FIGURE 4-6.
SITE 09 – ALLEN HARBOR LANDFILL
PROPOSED EXTRACTION WELL LOCATIONS

Date: 3/94 | Project No. 01042-0040

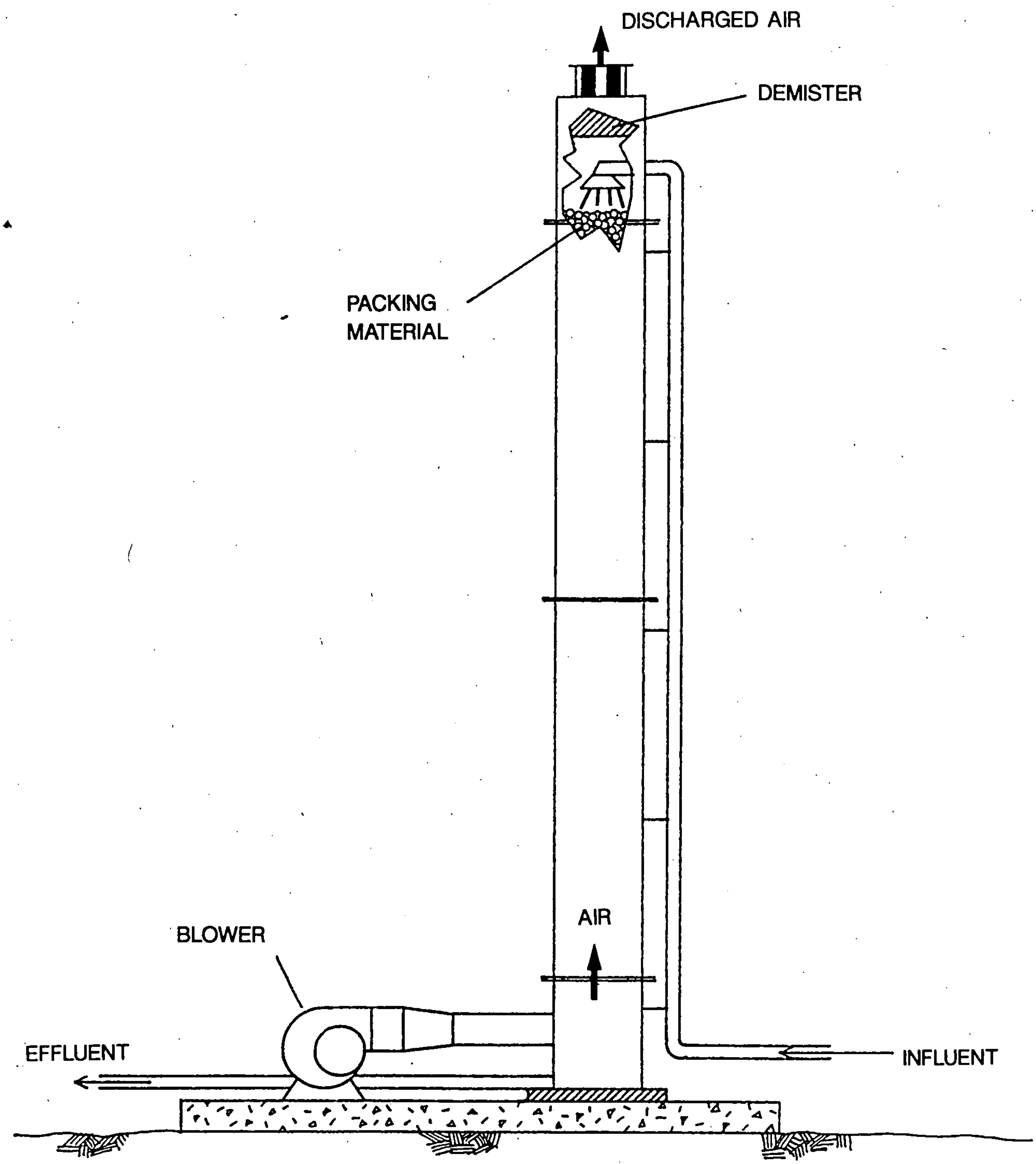

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FIGURE 4-7.

AIR STRIPPING UNIT

Date: 3/94 | Project No. 01042-0040

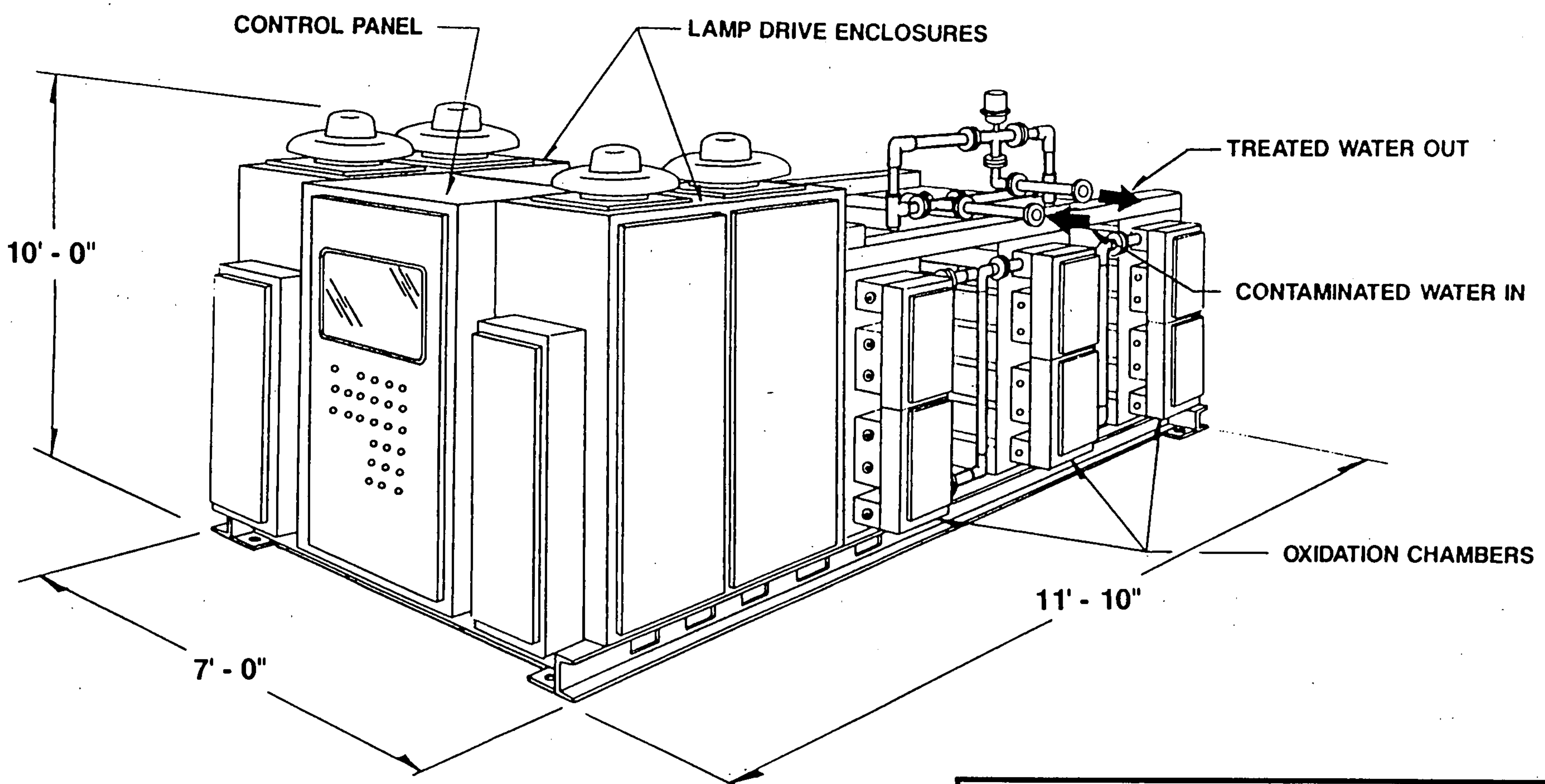

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FIGURE 4-8.
UV OXIDATION UNIT

Dat : 3/94 | Project No. 01042-0040

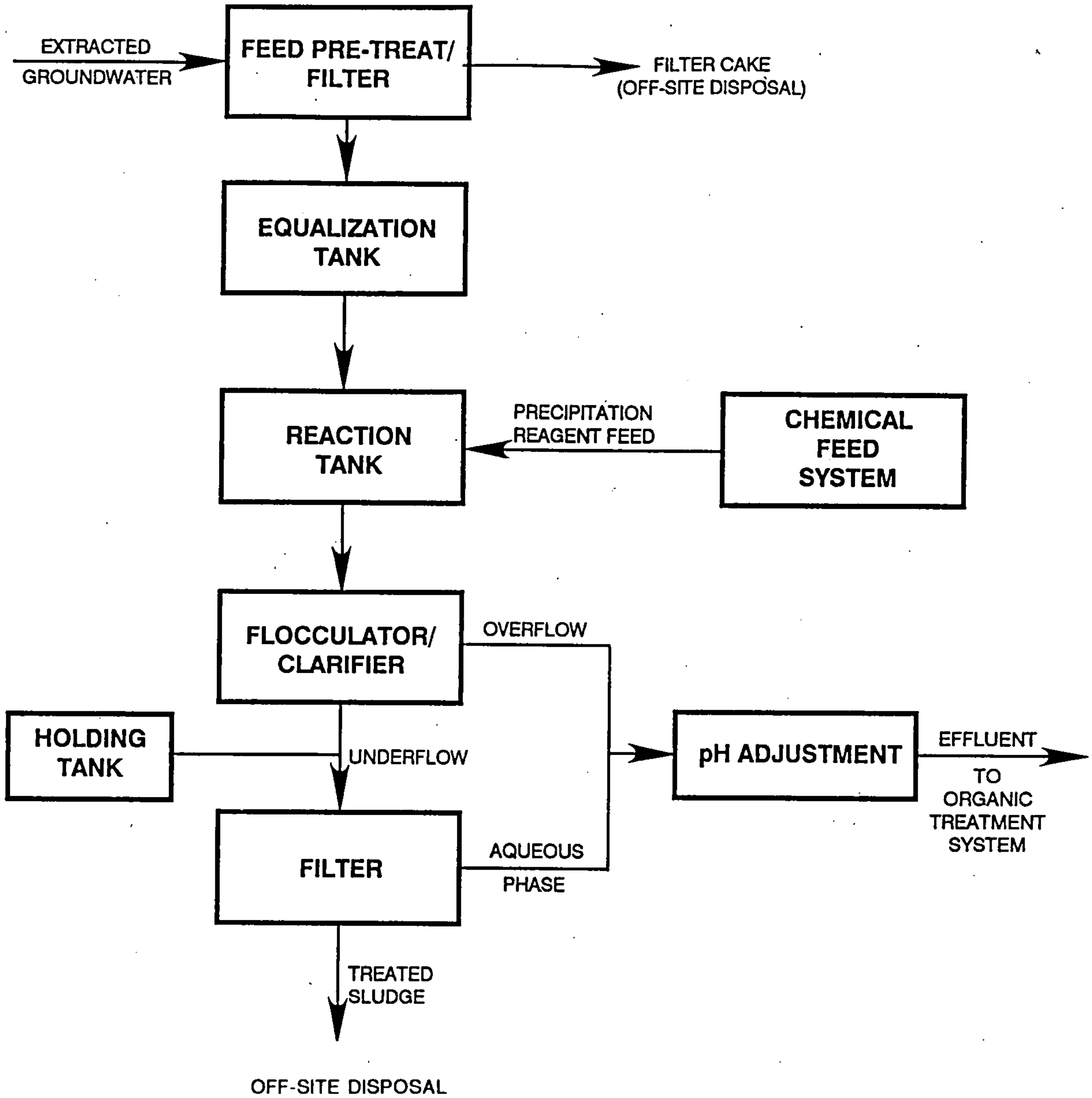

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FIGURE 4-9.
CHEMICAL PRECIPITATION SCHEMATIC

Date: 3/94 | Project No. 01042-0040

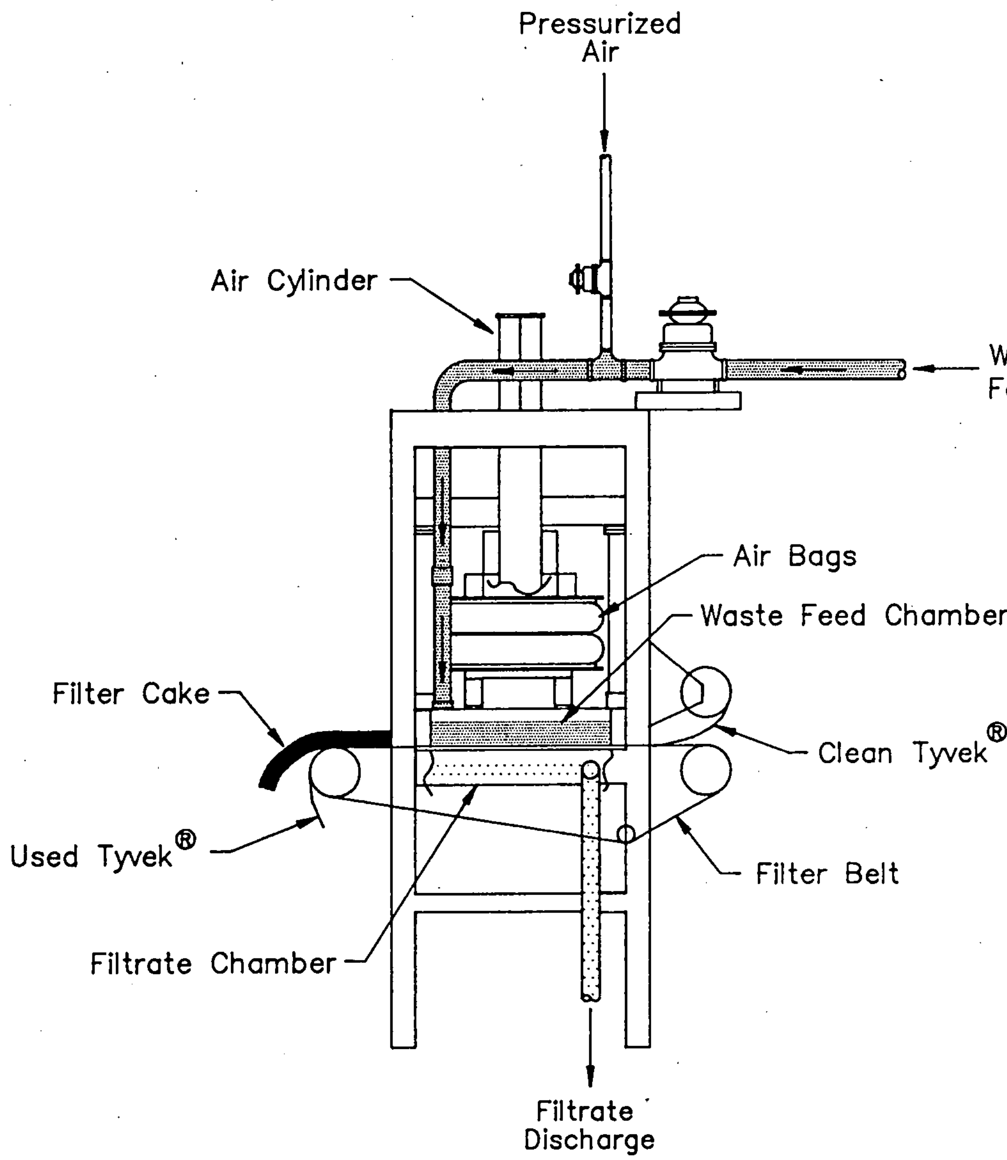

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FIGURE 4-10.

DUPONT/OBERLIN MICROFILTRATION SYSTEM

Date: 3/94 | Project No. 01042-0040

TABLE 2-1

SUMMARY OF WASTE MATERIAL DISPOSED AT
SITE 09 - ALLEN HARBOR LANDFILL

Type of waste material	Approximate period of disposal	Estimated total disposal
Ash from coal fired boilers at NAS Quonset Point	Prior to 1950	Unknown
Magnitron tubes (containing extremely low levels of radiation)	Unknown	2,000 tubes
Sludge from NAS Quonset Point Sewage Treatment Plant	1946 to 1969	11,000-13,800 cubic yards
Used turpentine and acetone	1960 to 1969	90-180 gallons
Asbestos from Construction Equipment Department (CED)	Early 1960's to 1969	810-1,080 cubic feet
Paint cans from CED	1947 to 1972	6,500-13,000 gallons
Carbide	1950's	250-300 lbs.
Paint thinner and degreasers	Unknown	Unknown
Jet fuel	1964 to 1967	3,300-4,950 gallons
Chromic acid from NAS Quonset Point plating operations	Unknown	Unknown
Oil drained from transformers, possibly containing PCBs	1960 to 1967	1,260 gallons
P-1 and P-2 preservatives	1967 to 1968	15,125 gallons
Hardened cement	1946 to 1947	8,084,000 pounds
Used mineral grit (black beauty)	1950 to 1972	1,100 tons
55-gallon drums which previously contained Stoddard solvent, trichloroethylene, carbon tetrachloride, sulfuric acid, nitric acid, and phosphoric acid	1950 to 1972	7,260 gallons[a]

TABLE 2-1

SUMMARY OF WASTE MATERIAL DISPOSED AT
SITE 09 - ALLEN HARBOR LANDFILL
(continued)

Type of waste material	Approximate period of disposal	Estimated total disposal
Drums of waste oil solvent and paint thinners from Bldg. T-1, W-3, and W-4	1947 to 1955	9,600 gallons
Waste carbon tetrachloride from NARF Quonset Point degreasing and cleaning operations	1946 to 1955	171,000 gallons
Waste trichloroethylene from NARF Quonset Point degreasing and cleaning operations	1955 to 1972	323,000 gallons
Mixed petroleum base oil	1946 to 1972	858,000 gallons
Waste coating materials	1946 to 1972	83,000 gallons
Plating wastes from NARF Quonset Point	1946 to 1972	39,000 gallons
Paint sludges from NARF Quonset Point	1946 to 1972	11,700 gallons

a - These quantities are based on a residue of 10 percent remaining in the drums or cans at the time of disposal.

Source: IAS (Hart, 1984)

TABLE 2-2

SITE 09 – ALLEN HARBOR LANDFILL
VERTICAL HYDRAULIC GRADIENTS

WELL CLUSTER NUMBER	VERTICAL DISTANCE (ft)(1)		HEAD DIFFERENCE (ft)(2)		GRADIENT (ft/ft)	
	8/13/93	9/17/93	8/13/93	9/17/93	8/13/93	9/17/93
09-MW02/03	22.94	22.49	0.31	1.16	1.35E-2	5.16E-2
09-MW06	43.93	43.26	-2.11	0.28	-4.80E-2	6.47E-3
09-MW07	34.12	33.52	-1.67	0.02	-4.89E-2	5.97E-4
09-MW08	48.26	48.84	0.21	1.82	4.35E-3	3.73E-2
09-MW09	45.16	45.82	-0.53	0.70	-1.17E-2	1.53E-2
09-MW10	54.42	55.25	0.53	1.98	9.74E-3	3.58E-2
09-MW13	42.20	42.04	0.21	0.39	4.98E-3	9.28E-3

NOTES: (1) The vertical distance is the difference in elevation between the water table in the shallow well and the middle of the screened interval in the deep well.

(2) The head difference is the elevation of the deep well piezometric level minus the water table elevation. Thus, negative signs represent downward gradients.

TABLE 2-3

SITE 09 – ALLEN HARBOR LANDFILL
AVERAGE HORIZONTAL HYDRAULIC GRADIENTS AND LINEAR VELOCITIES

LOCATION	AVERAGE HORIZONTAL GRADIENT (ft/ft) 8/13/93	AVERAGE HORIZONTAL GRADIENT (ft/ft) 9/17/93	AVERAGE LINEAR VELOCITY (ft/d) 8/13/93	AVERAGE LINEAR VELOCITY (ft/d) 9/17/93
SHALLOW WELLS:				
09–MW02S to 09–MW01S	6.62E–3	5.15E–3	0.38	0.30
09–MW04S to 09–MW02S	7.07E–3	6.21E–3	0.41	0.36
09–MW04S to 09–MW10S	1.69E–2	1.06E–2	0.97	0.61
09–MW05S to 09–MW01S	1.12E–2	1.02E–2	0.64	0.59
09–MW06S to 09–MW01S	1.22E–2	9.66E–3	0.70	0.56
09–MW06S to 09–MW08S	8.09E–3	4.20E–3	0.47	0.24
09–MW13S to 09–MW01S	6.97E–3	6.26E–3	0.40	0.36
DEEP WELLS:				
09–MW03D to 09–MW07D	1.55E–3	––	0.01	––
09–MW06D to 09–MW08D	8.71E–4	––	0.01	––
09–MW07D to 09–MW09D	2.58E–3	––	0.02	––
09–MW13D to 09–MW03D	4.74E–3	––	0.03	––
09–MW13D to 09–MW06D	3.23E–3	––	0.02	––
09–MW13D to 09–MW10D	3.59E–3	––	0.02	––
09–MW08D to 09–MW06D	––	5.91E–4	––	0.004
09–MW10D to 09–MW03D	––	1.76E–3	––	0.01
09–MW10D to 09–MW07D	––	1.41E–3	––	0.01
09–MW12D to 09–MW13D	––	9.61E–4	––	0.01

NOTES: The shallow and deep hydraulic conductivities for the site (11.5 ft/d and 1.0 ft/d, respectively) are the median values derived from the Phase II RI slug tests.
An effective porosity of 0.20 for silty sands (EPRI, 1985) was assumed.

TABLE 2-4

SITE 09 – ALLEN HARBOR LANDFILL
COMPARISON OF PHASE II SURFACE AND SUBSURFACE SOIL SAMPLE INORGANIC RESULTS TO OBSERVED BACKGROUND CONCENTRATIONS

ELEMENT	PHASE II SURFACE SOIL RANGES	PHASE II SUBSURFACE RANGES	OBSERVED BACKGROUND SURFACE SOIL CONCENTRATION RANGES (mg/kg)
Aluminum	2,360–23,700	3,060–18,300	1,710 – 12,600
Antimony	ND–37.5	ND–89.8	ND – 3
Arsenic	ND–28.3	2–17.2	0.59 – 8.1
Barium	8.3–116	8.9–643	5.6 – 19.8
Beryllium	ND–59.4	ND–5.6	ND – 0.77
Cadmium	ND–172	ND–65.7	ND – 0.46
Calcium	212–15,300	289–21,500	62.7 – 628
Chromium	5.4–291	4.2–154	3.5 – 11
Cobalt	ND–326	2.6–73	ND – 4.6
Copper	ND–6,620	7.4–1,560	ND – 14.8
Iron	7,040–185,000	5,390–156,000	5,960 – 13,200
Lead	5.1–4,320	3.9–2,130	3.4 – 55.9
Magnesium	602–8,200	594–9,230	325 – 1,220
Manganese	22.6–1,910	51.7–1,270	23.3 –150
Mercury	ND–2.8	ND–191	ND – 0.12
Nickel	ND–1,540	ND–227	ND – 7.5
Potassium	ND–1,910	518–1,620	ND – 728
Selenium	ND–1.6	ND–2	ND – 0.77
Silver	ND–14.6	ND–34.9	ND – 0.22
Sodium	ND–4,070	ND–2,640	ND – 161
Thallium	ND–8.3	ND	ND – 0.96
Vanadium	5.3–112	4.7–823	3.3 – 24.6
Zinc	14.4–32,900	17.4–6,700	10.3 – 172
Cyanide	ND–0.66	ND–1.1	ND – 0.60

NOTE:
ND Indicates that the element was not detected in the soil sample.

TABLE 2–5
SITE 09 – ALLEN HARBOR LANDFILL
SUMMARY OF CANCER AND NON–CANCER RISK ESTIMATES FOR ALL SCENARIOS

Pathway	CANCER RISKS					
	Scenario 1 (Construction Worker)		Scenario 2 (Recreational)		Scenario 3 (Commercial/Industrial Worker)	
	Geometric Mean	RME	Geometric Mean	RME	Geometric Mean	RME
Incidental ingestion of soil	4E–06	1E–04	1E–05	6E–04	––	––
Dermal contact with soil	2E–08	1E–07	6E–07	7E–06	––	––
Inhalation of particulates	6E–09	4E–08	––	––	––	––
Ingestion of ground water	––	––	––	––	2E–04	5E–02

[shaded] = Cancer risk > 1E–6

Pathway	NON–CANCER HAZARD INDICES					
	Scenario 1 (Construction Worker)		Scenario 2 (Recreational)		Scenario 3 (Commercial/Industrial Worker)	
	Geometric Mean	RME	Geometric Mean	RME	Geometric Mean	RME
Incidental ingestion of soil	3E–01	3E+00	4E–02	1E+00	––	––
Dermal contact with soil	3E–04	6E–03	4E–05	4E–03	––	––
Inhalation of particulates	2E–03	2E–02	––	––	––	––
Ingestion of ground water	––	––	––	––	2E+00	4E+01

[shaded] = Hazard index > 1E+0

TABLE 3 – 1

Site 09 – Allen Harbor Landfill

Comparison of Maximum Soil Contaminant Levels to Action Levels

Parameter	Maximum Concentration Detected (ppm) Surface Soils (0–2') Phase I RI	Maximum Concentration Detected (ppm) Surface Soils (0–2') Phase II RI	Federal Action Level (ppm)	State Action Levels Guidance Level (ppm)	State Action Levels Regulatory Level (ppm)
PCBs	4.9	30	10(1)	--	10/50(3)
LEAD	8710	4320	500–1,000(2)	300(4)	--

ND – Not Detected

(1) TSCA (40 CFR 761); Requirements for decontaminating spills in nonrestricted access areas.

(2) USEPA, OSWER Directive 9355.4–02, Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites.

(3) RIDEM Rules and Regulations for Solid Waste Management Facilities defines solid waste as including any soil debris or other material with a concentration of 10 ppm or greater PCBs.
RIDEM Rules and Regulations for Hazardous Waste Management defines Type 6 – extremely hazardous waste as including waste which contains 50 ppm or greater PCBs.

(4) RIDEM and RI Dept. of Health–Risk Assessment Guidance Level.

TABLE 3-2
SITE 09 - ALLEN HARBOR LANDFILL
COMPARISON OF DETECTED GROUND WATER CONTAMINANTS TO
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) OR TO-BE-CONSIDERED REQUIREMENTS (TBCs)

Parameter	Maximum Concentration Detected in Ground Water: Phase I (ppb)		Phase II (ppb)		--FEDERAL ARARs/TBCs-- WATER QUALITY CRITERIA(1): AQUATIC LIFE: MARINE ACUTE CRITERIA (ppb)	AQUATIC LIFE: MARINE CHRONIC CRITERIA (ppb)	HUMAN HEALTH: FISH CONSUMPTION ONLY (ppb)	-RHODE ISLAND ARARs/TBCs- SALTWATER(2) AQUATIC LIFE CRITERIA: ACUTE (ppb)	SALTWATER(2) AQUATIC LIFE CRITERIA: CHRONIC (ppb)
Volatile Organics (ppb)	Monitoring Wells	TP9-3	Shallow	Deep					
Benzene	3 J	2 J	11		5100	700	40		
Chlorobenzene	18		620	2 J					
1,2-Dichloroethane				320 J	113000		243		
Ethylbenzene	31		87		430		3280		
1,1,2,2-Tetrachloroethane					9020**	9020**	10.7		
Tetrachloroethene			670		10200	450	8.85		
Toluene	2 J	1 J	28		6300	5000	424000		
Trichloroethene	3 J		74	1200 J	2000**	2000**	80.7		
1,1,2-Trichloroethane				48			41.8		
Vinyl Chloride	13		25	7000			525		
Acetone	8 J								
Xylenes (total)	55		190						
1,2-Dichloroethene (total)	72		510	28000	224000**	224000**			
1,2-Dichloropropane			940	230 J					
Semivolatiles (ppb)									
Bis(2-Chloroethyl)ether	3 J								
Bis(2-Chloroisopropyl)ether	3 J								
1,3-Dichlorobenzene			83						
1,4-Dichlorobenzene			420						
1,2-Dichlorobenzene			8 J						
Naphthalene	5 J	3 J			2350				
Pentachlorophenol			2 J		13	7.9			
Phenanthrene		2 J			7.7*	4.6*			
Pyrene		2 J							
2-Methylnaphthalene	3 J	2 J							
1,2,4-Trichlorobenzene			8 J						
Benzoic acid		3 J							
PCBs		20			10	0.03	0.000079	10	0.03
Inorganics (ppb)									
Antimony	71	159	47.4		1500*	500*	45000		
Arsenic	5.4	9.7	16.3 J	5.5	69	36	0.0175	69	36
Beryllium	2.7						0.0641		
Cadmium	5.2	32		0.28 J	43	9.3		43	9.3
Chromium	13.5	63	8.7	26.3	1100+	50+		1100 +	50 +
Copper	72	470	8.2	13.2	2.9	2.9		2.9	2.9
Lead	25.5	1380	3.6 J	2.9 J	140	5.6		140	5.6
Mercury	0.32	2.3			2.1	0.025	0.146	2.1	0.025
Nickel		60.1	18.6		75	8.3	100	75	8.3
Silver		10.8			7.2*	0.92*		2.3	
Thallium			3.9 J		2130		48		
Zinc	165	2,940	142 J	65.4 J	95	86		95	86
Barium	156	1,780	753	278					
Iron	11,500	48,000	25500	47300					
Manganese	1910	1,080	791	1420			100		
Vanadium	23	45.6							
Aluminum	37,700	11,800	355 J	7240					
Cobalt	49.6	17.6	13.9	43.4					
Magnesium	10,800	27,200	60700	57500					
Calcium	71,800	148,000	140000	127000					
Sodium	137,000	15,500	200000	230000					
Potassium	7,160	11,800	38500	14600					

(1) - USEPA, 1991.

(2) - Rhode Island Water Quality Standards - Class-specific criteria require no constituents in concentrations or combinations which would be harmful to human, animal, or aquatic life or which woul make the waters unsafe or unsuitable for fish or shellfish or their propogation, impair the palatability of same, or impair the waters for any other uses.

+ - Represents standard for hexavalent chromium (Chromium VI), which is more stringent than criteria for trivalent chromium (Chromium III). Maximum concentration detected in ground water is reported as total chromium.

* - Proposed criteria.

** - Insufficient data to develop criteria. Value presented is the L.O.E.L. - Lowest Observed Effect Level.

TABLE 3-3

SITE 09 - ALLEN HARBOR LANDFILL

COMPARISON OF DETECTED SURFACE WATER CONTAMINANTS TO

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) OR TO-BE-CONSIDERED REQUIREMENTS (TBCs)

Parameter	Maximum Concentration Detected in Surface Water Phase II (ppb)		--FEDERAL ARARs/TBCs-- WATER QUALITY CRITERIA (1): AQUATIC LIFE MARINE ACUTE CRITERIA (ppb)	AQUATIC LIFE MARINE CHRONIC CRITERIA (ppb)	HUMAN HEALTH FISH CONSUMPTION ONLY (ppb)	-RHODE ISLAND ARARs/TBCs- SALTWATER(2) AQUATIC LIFE CRITERIA: ACUTE (ppb)	CHRONIC (ppb)
Volatile Organics (ppb)	09-SW09	09-SW10					
1,1,2,2-Tetrachloroethane		3 J	9020**	9020**	10.7		
Trichloroethene		2 J	2000**	2000**	80.7		
1,2-Dichloroethene (total)		6 J	224000**	224000**			
Carbon disulfide	2 J						
Inorganics (ppb)							
Aluminum							
Arsenic		4.2	69	36	0.0175	69	36
Cadmium		0.14	43	9.3		43	9.3
Chromium		11.6 J	1100++	50++		1100	50
Iron	580	7270					
Manganese	41	137			100		
Vanadium		12.1					
Magnesium	35400	190000					
Calcium	19900	68100					
Sodium	289000	1750000					
Potassium	12800	69100					

(1) - USEPA, 1991.

(2) - Rhode Island Water Quality Standards - Class-specific criteria require no constituents in concentrations or combinations which would be harmful to human, animal, or aquati would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the waters for any other uses.

+ - Represents standard for hexavalent chromium (Chromium VI) which is more stringent than criteria for trivalent chromium (Chromium III). Maximum concentration detected in ground water is reported as total chromium.

* - Proposed criteria.

** - Insufficient data to develop criteria. Value presented is the L.O.E.L. -Lowest Observed Effect Level.

TABLE 3-4
SITE 09 – ALLEN HARBOR LANDFILL
COMPARISON OF DETECTED LEACHATE CONTAMINANTS TO
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) OR TO-BE-CONSIDERED REQUIREMENTS (TBCs)

Parameter	Maximum Concentration Detected in Leachate Phase I (ppb)	--FEDERAL ARARs/TBCs-- WATER QUALITY CRITERIA (1) AQUATIC LIFE MARINE ACUTE CRITERIA (ppb)	AQUATIC LIFE MARINE CHRONIC CRITERIA (ppb)	HUMAN HEALTH FISH CONSUMPTION ONLY (ppb)	-RHODE ISLAND ARARs/TBCs- SALTWATER(2) AQUATIC LIFE CRITERIA ACUTE (ppb)	SALTWATER(2) AQUATIC LIFE CRITERIA CHRONIC (ppb)
Volatile Organics (ppb)						
1,2-Dichloroethane	10	113000		243		
1,1,2,2-Tetrachloroethane	2 J	9020**	9020**	10.7		
Vinyl Chloride	3 J			525		
1,2-Dichloroethene (total)	21	224000**	224000**			
Semivolatiles (ppb)						
Benzo(a)anthracene	5 J					
Benzo(a)pyrene	3 J					
Benzo(b,k)fluoranthene	7 J					
Benzo(g,h,i)perylene	4 J					
Bis(2-Ethylhexyl)phthalate	2 J					
Chrysene	4 J					
Fluoranthene	8 J	40	16	54		
Indeno(1,2,3-cd)pyrene	3 J					
Phenanthrene	4 J	7.7*	4.6*			
Pyrene	6 J					
Pentachlorophenol	10J	13	7.9			
Benzoic acid	2 J					
PCBs	13	10	0.03	0.000079	10	0.03
Inorganics (ppb)						
Aluminum						
Antimony	102	1500*	500*	45000		
Arsenic	38.5	69	36	0.0175	69	36
Beryllium	10.2			0.0641		
Cadmium	260	43	9.3		43	9.3
Chromium	252	1100+	50+		1100 +	50 +
Copper	11,400	2.9			2.9	2.9
Lead	8,250	140	5.6		140	5.6
Mercury	5	2.1	0.025	0.146	2.1	0.025
Nickel	1,660	75	8.3	100	75	8.3
Selenium	50.2	300	71		410	54
Silver	22.6	7.2*	0.92*		2.3	
Thallium	41.8	2130		48		
Zinc	33,600	95	86		95	86
Barium	1,070					
Iron	145,000					
Manganese	24,400			100		
Vanadium	256					
Aluminum	60,700					
Cobalt	480					
Magnesium	894,000					
Calcium	270,000					
Sodium	67,800,000					
Potassium	279,000					

(1) – USEPA, 1991.

(2) – Rhode Island Water Quality Standards – Class-specific criteria require no constituents in concentrations or combinations which would be harmful to human, animal, or a would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the waters for any other uses.

+ – Represents standard for hexavalent chromium (Chromium VI) which is more stringent than criteria for trivalent chromium (Chromium III). Maximum concentration detected ground water is reported as total chromium.

* – Proposed criteria.

** – Insufficient data to develop criteria. Value presented is the L.O.E.L. – Lowest Observed Effect Level.

TABLE 3-5
SITE 09 – ALLEN HARBOR LANDFILL
SUMMARY OF RISK-BASED PRELIMINARY REMEDIATION GOALS (PRGs) – SURFACE SOILS

Parameter	Surface Soils Maximum Detected Concentration (ppm)	Estimated Reasonable (1) Maximum Exposure Cancer Risk Youth (2-18 years)	10^{-6} Risk-Based(2) Cleanup Level (ppm)
Benzo(a)anthracene	69	8.4×10^{-5}	0.82
Benzo(a)pyrene	45	5.5×10^{-5}	0.82
Benzo(b/k)fluoranthene	220	2.7×10^{-4}	0.82
Chrysene	63	7.6×10^{-5}	0.82
Dibenzo(a,h)anthracene	6.5	7.9×10^{-6}	0.82
Indeno(1,2,3-cd)pyrene	24	2.9×10^{-5}	0.82
2,3,7,8-TCDD equivalents	0.00002144(3)	6.4×10^{-6}	0.000036(3)
Arsenic	32.5	9.5×10^{-6}	3.3(4)
Beryllium	75.4	5.4×10^{-5}	1.4

(1) – Risk estimates represent total cancer risk due to ingestion and dermal contact under future recreational use, as presented in the Draft Remedial Investigation Report (TRC, 1993e).

(2) – See Appendix B for discussion of risk-based PRG calculations.

(3) – Maximum detected concentration of 2,3,7,8 – TCDD equivalents does not exceed 1×10^{-6} risk-based cleanup level.

(4) – PRG is less than the upper range of 8.1 mg/kg for background arsenic soil levels at NCBC. See Table 2-4.

TABLE 3-6
SITE 09 – ALLEN HARBOR LANDFILL
COMPARISON OF SEDIMENT COC CONCENTRATIONS TO NOAA ER-L AND ER-M VALUES

Parameter	NOAA ER-L (µg/kg)	NOAA ER-M (µg/kg)	MARINE SEDIMENT SD09	MARINE SEDIMENT SD10
Total Organic Carbon			22600	2020
Volatile Organic Compounds (µg/kg)				
Benzene	NA	NA	7	ND
Toluene	NA	NA	ND	ND
Semivolatile Organic Compounds (µg/kg)				
Naphthalene	340	2100	530	ND
2-Methylnaphthalene	65	670	230	ND
Acenaphthene	150	650	1400	ND
Dibenzofuran	NA	NA	840	ND
Fluorene	35	640	1700	ND
Phenanthrene	225	1380	11000	ND
Anthracene	85	960	2200	ND
Carbazole	NA	NA	1900	ND
Fluoranthene	600	3600	11000	ND
Pyrene	350	2200	9200	ND
Benzo(a)anthracene	230	1600	7200	ND
Chrysene	400	2800	5400	ND
Benzo(b)fluoranthene	NA	NA	8600	ND
Benzo(k)fluoranthene	NA	NA	8600	ND
Benzo(a)pyrene	400	2500	4300	ND
Indeno(1,2,3-cd)pyrene	NA	NA	3100	ND
Dibenzo(a,h)anthracene	60	260	990	ND
Benzo(g,h,i)perylene	NA	NA	3100	ND
Total PAHs (µg/kg)	4000	35000	78550	ND
Pesticides/PCB Organic Compounds (µg/kg)				
Heptachlor epoxide	NA	NA	8.1	ND
Dieldrin	0.02	8	2.9	ND
4,4'-DDE	2	15	ND	1.2
4,4'-DDD	2	20	32	ND
Endosulfan sulfate	NA	NA	3	ND
Endrin ketone	NA	NA	9.4	ND
Alpha chlordane	0.5	6	0.5	1
Gammma chlordane	0.5	6	ND	0.86
PCB-1260	NA	NA	ND	590
Total PCBs (µg/kg)	50	400	ND	590
Inorganic Compounds (mg/kg)	(mg/kg)	(mg/kg)		
Antimony	2	25	17.9	3.8
Arsenic	33	85	59.2	8.3
Beryllium	NA	NA	ND	ND
Cadmium	5	9	4960	769
Cobalt	NA	NA	141	158
Copper	70	390	46300	48800
Lead	35	110	5440	725
Mercury	0.15	1.3	29.7	11.3
Selenium	NA	NA	1.8	ND
Silver	1	2	R	388
Thallium	NA	NA	71.8	ND
Vanadium	NA	NA	ND	147
Zinc	120	270	ND	ND

Shaded values exceed the ER-M.

ND = Not Detected

NA = Not Available

R = Sample result rejected during data validation.

TABLE 3-7
SITE 09 - ALLEN HARBOR LANDFILL
COMPARISON OF DETECTED SOIL CONTAMINANTS TO CALCULATED LEACHING MODEL LEVELS

Constituent	Maximum Concentration Detetcted In Unsaturated Soils (ppm)	Maximum Modeled[1] Unsaturated Concentration (ppm)	Maximum Concentration Detected In Saturated Soils (ppm)	Modeled Maximum[1] Saturated Concentration (ppm)
Volatile Organics				
Benzene	1.5	5.78	0.003	0.00510
Chloroform	0.002	76.3	--	0.0674
1,2-Dichloroethene[2]	0.014	18.1/25.8	3.1	0.0160/0.0228
1,1,1-Trichloroethane	0.013	505	0.004	0.446
Trichloroethene	3.8	14.5	0.002	0.0128
Tetrachloroethene	0.012	14.5	--	0.0128
Toluene	15000	4190	0.082	3.70
Ethylbenzene	910	8450	0.038	7.46
Xylenes	4200	85600	0.11	75.6
Semivolatiles				
Bis(2-ethylhexyl)phthalate	33	10300	0.76	9.06
Butylbenzylphthalate	13	51600	0.27	45.6
Chrysene	17	419	320	0.370
1,2-Dichlorobenzene	63	12300	--	10.9
1,4-Dichlorobenzene	0.18	1590	0.11	1.40
Indeno(1,2,3-cd)pyrene	25	156000	79	138
Dibenzo(a,h)anthracene	7.4	2400	29	2.12
Benzo(a)anthracene	69	349	420	0.308
Benzo(a)pyrene	45	1630	150	1.44
Benzo(k)fluoranthene	110	11900	490	10.5
Pesticides/PCBs				
Chlordane	0.039	14600	0.013	12.9
Endrin	0.026	6820	0.097	6.02
PCBs	30	34900	0.13	30.8

(1) See Appendix C for model description and associated calculations.
(2) Separate cleanup levels were calculated using MCL values for both the cis- and trans- isomers of 1,2-dichloroethane.

TABLE 3-8
SITE 09 – ALLEN HARBOR LANDFILL
COMPARISON OF MAXIMUM DETECTED TCLP LEVELS TO RCRA LIMITS

Constituent	Maximum Detected Concentration (ppm) Phase I	Phase II	RCRA[1] Limits (ppm)
Volatile Organics			
Benzene	0.004 J		0.5
Ethylbenzene	0.003 J		
Toluene	0.005		
Trichloroethene	0.003 J		0.5
Styrene	0.010		
Acetone	0.036		
2-Butanone	0.009 J		
4-Methyl-2-pentanone	0.030		
Xylenes (Total)	0.021		
1,2-Dichloroethene (Total)	0.001 J		
Semi-volatiles			
Fluorene	0.002 J		
Napthalene	0.011		
Phenanthrene	0.006 J		
Benzyl alcohol	0.150		
2-Methylnaphthalene	0.024		
2-Chlorophenol	0.002 J		
2,4-Dimethylphenol	0.003 J		
4-Methylphenol	0.007 J		
Benzoic acid	0.110		
Inorganics			
Antimony	0.537		
Arsenic	0.0545		5.0
Beryllium	0.0068 J		
Cadmium	0.311	2.67	1.0
Chromium	0.134		5.0
Copper	2.030		
Lead	2.670		5.0
Mercury	0.0035		0.2
Nickel	0.366		
Silver	0.157		5.0
Zinc	7.880		
Barium	1.8		100.0
Iron	70.8		
Manganese	5.6		
Vanadium	0.25		
Aluminum	114.0		
Cobalt	0.0743		
Magnesium	22.3		
Calcium	413.0		
Sodium	1480.0		
Potassium	8.770		
Cyanide	0.0114		

(1) 40 CFR 261.24 – Maximum contaminant concentrations for the toxicity characteristic.

TABLE 3-9
SOIL/WASTE REMEDIAL TECHNOLOGY SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

Screened on Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
No Action	None	Not Applicable	No action.	Required for consideration under the NCP.
Institutional Control	Site Use Restrictions	Deed Restrictions	Deed for site would be revised to include restrictions on future site use or development, limiting future exposures to site contaminants.	Potentially applicable; implemention dependent on base closure process.
		Fencing	Fencing and posting of warning signs to limit public access and exposure to site contaminants.	While public access to NCBC Davisville is currently limited, additional fencing could further limit future access once base is closed.
Containment	Surface Controls	Grading	Grading would reshape topography to minimize poor drainage areas, run–on, run–off and soil erosion.	Potentially viable; may be combined with the implementation of other technologies (e.g., capping).
		Revegetation	By adding or maintaining vegetation on the surface of the site, erosion is minimized and ecological habitat value is enhanced or maintained.	Existing site is fairly well–covered by vegetation; may be combined with the implementation of other technologies (e.g., capping).

TABLE 3–9 (Continued)
SOIL/WASTE REMEDIAL TECHNOLOGY SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

Shaded box: Screened on Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
Containment (Cont.)	Capping	Native Soil	Native soils are used to cap the site, preventing direct contact and minimizing erosion.	Potentially viable; supports revegetation of site with deep–rooted vegetation.
		RCRA Subtitle C Hybrid Cap	Capping of site with a cap that addresses potential direct contact threats but does not necessarily limit infiltration if the site poses no ground water threat.	Potentially viable; utilizes a hybrid cap to comply with relevant and appropriate RCRA requirements.
		RCRA Subtitle C Landfill Cap	Capping of site with a cap that addresses potential direct contact threats and minimizes long–term migration of liquids; typically employs a double–barrier layer (i.e., combined synthetic and soil barrier)	Potentially viable, minimizes direct exposure and infiltration; meets state and federal hazardous waste landfill closure requirements.

TABLE 3–10
GROUND WATER/LEACHATE REMEDIAL TECHNOLOGY SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

Screened On Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
No Action	None	Not Applicable	No action.	Fulfills NCP requirement for consideration of no action alternative.
Institutional Control	Long – Term Monitoring	Not Applicable	Ground water quality monitoring. Could also include surface water and sediment monitoring.	Would provide monitoring of water quality and potential contaminant migration.
	Ground Water Use Restrictions	Deed Restrictions	Legal restrictions on ground water use in the contaminated area.	Would prevent future exposures to existing ground water contamination by restricting future installation of on–site wells.
		Alternate Water Supply	Provision of alternate water supply to receptors impacted by ground water contamination.	No potable ground water receptors have been impacted.
Containment	Capping	Various	Limits infiltration and leaching of contamination into ground water.	Potentially viable, especially when combined with use of capping as a soil remedial technology.
	Vertical Barrier	Slurry Wall	Impermeable barrier formed by back–filling trench below the ground water table with a low permeability material.	Potentially viable for limiting migration of contaminated ground water.
		Sheet Piling	Sheet piling is driven into soil to form a barrier wall.	Potentially viable for limiting migration of contaminated ground water.

TABLE 3-10 (Continued)
GROUND WATER/LEACHATE REMEDIAL TECHNOLOGY SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

Screened On Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
Extraction/ Treatment/ Discharge	Extraction	Extraction Wells	Wells and pumping system used for extraction of contaminated ground water or leachate.	Potentially viable, proven technology.
		Well Points	Manifold system of extraction points connected to common collection source.	Most suitable for shallow ground water extraction; depth to water table limits implementability.
		Interceptor Trench	Placement of trench with high permeability materials, used to divert ground water flow.	Most suitable for shallow ground water extraction; depth to water table and presence of subsurface waste materials limits implementability.
	Off-site Treatment	Off-site POTW	Extracted ground water discharged to local POTW for treatment.	Regulations often prohibit discharge of subsurface water to sewer systems; organics may not be treatable by POTW treatment system.
		Off-site RCRA Facility	Extracted ground water discharged to licensed RCRA facility for treatment and/or disposal.	High ground water extraction rates and distance to RCRA facility prohibit feasibility of this treatment option.
	Biological/Physical/ Chemical Organic Treatment	Bioreactor	Activated sludge process utilizes acclimated bacteria for aerobic degradation of contaminants.	Proven effective for VOCs and some BNA compounds, ineffective for inorganics.

TABLE 3-10 (Continu d)
GROUND WATER/LEACHATE REMEDIAL TECHNOLOGY SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

Screened On Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
Extraction/ Treatment/ Discharge (continued)	Biological/Physical/ Chemical Organic Treatment (continued)	PACT TM	Organic contaminants removed from ground water using powdered activated carbon combined with conventional biological treatment.	Applicable to VOCs, including aromatic hydrocarbons, BNAs, and pesticides. Ineffective for inorganics.
		Air Stripping	Transfer of volatile organic compounds to gaseous fraction through mixing with large volumes of air in a packed column.	Applicable to VOC contaminants, including aromatic hydrocarbons. Ineffective for inorganics, or compounds with low vapor pressures.
		Steam Stripping	Similar to air stripping but the use of steam increases contaminant volatilization.	Applicable to volatile organic contaminants and organics not readily stripped in a regular air stripping system.
		Carbon Adsorption	Contaminants adsorbed to activated carbon by internal pores of carbon granules.	Applicable to organic contaminants, including aromatic hydrocarbons. Ineffective for inorganics.
		Resin Adsorption	Similar to carbon adsorption but synthetic resins are used.	Can be effective for organic removal.
		UV Oxidation	An oxidizing agent such as hydrogen peroxide is mixed with the waste stream and exposed to ultraviolet light to oxidize contaminants.	Proven for treatment of VOCs, semi-volatiles & pesticides/PCBs in EPA SITE testing; ineffective in treatment of single-bonded hydrocarbons (e.g., 1,1,1-TCA).

TABLE 3–10 (Continued)
GROUND WATER/LEACHATE REMEDIAL TECHNOLOGY SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

Screened On Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
Extraction/ Treatment/ Discharge (continued)	Inorganic Treatment	Ion Exchange	Contaminants removed from aqueous phase by exchanging places with ions held by ion exchange material.	Effective for inorganics; ineffective for organics, which are not readily ionized.
		Precipitation	Contaminants removed by decreasing solubility.	Effective for inorganics; ineffective for organics, which generally have solubilities less affected by pH adjustments.
		Membrane Microfiltration	Solid particles removed from liquids using pressure filter.	SITE program technology; applicable to ground water contaminated with suspended heavy metals.
		Filtration	Suspended particles are removed from the ground water stream using conventional filtration methods.	Effective for removal of suspended solids contaminated with heavy metals.
		Electrochemical	Utilizes the oxidation/reduction properties of ferrous ions for removing heavy metals from aqueous solutions.	Proven for treatment of heavy metals; ineffective for organics, which are not readily ionized.

TABLE 3–10 (Continued)
GROUND WATER/LEACHATE REMEDIAL TECHNOLOGY SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

(Shaded) Screened On Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
Extraction/ Treatment/ Discharge (Cont.)	In–Situ Treatment (shaded)	Air Sparging (shaded)	Removal of volatile ground water components through the addition of air injected into ground water. Nutrients may be added to augment biodegradation.	Effective in treating hydrocarbons, high vapor pressure compounds, and compounds which are readily biodegraded; less effective on semi–volatiles; not effective for PCBs or inorganics; ineffective in low permeability geology; heterogeneity of subsurface wastes expected to reduce effectiveness.
		Biodegradation (shaded)	Nutrients and/or enhanced microorganisms are added to ground water to augment natural biodegradation.	Effective for fuel products; not effective for inorganics or compounds resistant to degradation; limited to geologies favoring aerobic conditions; heterogeneity of subsurface wastes would reduce transport of nutrients.
	Discharge	Ground Water	Treated water is recharged to the ground water via wells and/or infiltration galleries.	Potentially viable; recharge in existing waste disposal area may not be desirable.
		Surface Water	Treated water is discharged directly into surface water.	Potentially viable.
		Sanitary Sewer/ POTW	Treated water is discharged indirectly to surface water body via sanitary sewer and POTW.	Regulations may prohibit discharge of ground water to sewer system.

TABLE 3-11
SEDIMENT REMEDIAL TECHNOLOGY SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

(shaded) Screened on Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
No Action	None	Not Applicable	No action.	Required for consideration under the NCP.
Institutional Control	Site Use Restrictions	Deed Restrictions	Deed for site would be revised to include restrictions on future site use or development, limiting future exposures to or disruption of contaminated sediments.	Potentially applicable; implemention dependent on base closure process.
		Fencing (shaded)	Fencing and posting of warning signs to limit public access and exposure to contaminated sediments.	Fencing would not limit access to shoreline areas from the water.
		Long – Term Monitoring	Sediment quality adjacent to the landfill would be monitored over time to identify any changes in sediment quality.	Would identify any changes in sediment quality which could result in increased environmental risks.
Containment	Capping	Stone	Stone would be placed over contaminated sediments along toe of landfill face to provide protection against benthic organisms as well as wave and storm surge protection.	Potentially viable; would provide epibenthic organisms with suitable substrate for habitat and would prevent sediments from acting as continued exposure pathway.

TABLE 3–12
SOIL/WASTE PROCESS OPTION SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

● Representative Process Option

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
No Action	None	Not Applicable	● Is not effective in addressing soil contamination which exceeds TBCs or risk–based cleanup levels.	No implementation is required.	No cost.
Institutional Control	Site Use Restrictions	Deed Restrictions	● Limits disturbance of existing contamination, unacceptable future site use, or introduction of additional contaminated materials.	Requires appropriate legal authority.	Low capital cost.
		Fencing	● Limits human exposure to site and therefore potential direct contact with surficial contaminants; would prohibit future recreational site use.	Easily implemented.	Low capital cost; low maintenance cost..
Containment	Surface Controls	Grading	● Controls run–on and run–off and limits erosion of surficial contaminants.	Fairly easily implemented.	Low capital cost; low maintenance cost.
		Revegetation	● Limits erosion due to the soil–holding characteristics of vegetative cover; supports ecological resources.	Site is fairly well covered by vegetation under existing conditions and supports a variety of plant and animal species; if surface is disturbed by other activities, revegetation would be fairly easily implemented although remedial action selected may limit the type of vegetation used.	Low capital cost; low maintenance cost.

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TABLE 3-12 (Continued)
SOIL/WASTE PROCESS OPTION SCREENING
SITE 09 - ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

● Representative Process Option

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
Containment (Cont.)	Capping	Native Soil	● Effective in preventing direct contact and minimizing erosion; does not limit infiltration or control landfill gas emissions; could support deeper-rooted vegetation.	Fairly easily implemented; requires future land use restrictions, stripping of existing vegetation, grading, and revegetation of the site; does not comply with RCRA landfill closure requirements.	Moderate capital; low maintenance.
		RCRA Subtitle C Hybrid Cap	● Effective in preventing direct contact and minimize infiltration; supports shallow-rooted vegetative cover;	Implementation depends on specific restrictions, stripping of existing vegetation, grading and revegetation of the site; compliance with solid waste landfill closure regulations dependent on specific design; meets relevant and appropriate RCRA landfill closure requirements.	Moderate to high capital; moderate maintenance.
		RCRA Subtitle C Landfill Cap	● Effective in preventing direct contact and minimizing erosion, infiltration and leachate seeps; supports shallow-rooted vegetative cover; synthetic barrier is susceptible to physical damage if cap is disturbed.	Multi-layer design complicates construction; requires future land use restrictions, stripping of existing vegetation, grading, revegetation of the site and specialized construction methods; design exceeds relevant and appropriate RCRA landfill closure requirements.	High capital; moderate maintenance.

TABLE 3–13
GROUND WATER PROCESS OPTION SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

● Representative Process Option

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
No Action	None	Not Applicable	● Not effective in prohibiting or monitoring contaminant migration.	No implementation required.	No cost.
Institutional Control	Long Term Monitoring	Not Applicable	● Would provide means of monitoring contaminant migration but provides no treatment.	Easily implemented.	Low capital; moderate O&M.
	Ground Water Use Restrictions	Deed Restrictions	● Effective in limiting public exposures to ground water contaminants by eliminating installation of wells in contaminated areas.	Requires legal authority.	Moderate capital.
Containment	Capping	Various	● Can limit infiltration; requires appropriate drainage control to prevent surface water ponding.	Easily implemented; requires future land use restrictions.	Low capital; moderate maintenance.
	Vertical Barriers	Slurry Wall	Limits ground water movement; effective if keyed into natural impermeable materials.	Difficult to implement along seaward shore of landfill due to presence of waste to shoreline.	Moderate capital; low O&M.
		Sheet Piling	● Limits ground water movement; effective if keyed into natural impermeable materials.	Fairly easily implemented.	Moderate capital; low O&M.
Extraction/ Treatment/ Discharge	Extraction	Extraction Wells	● Effective; best suited for steep hydraulic gradients and miscible	Easily implemented.	Moderate capital; moderate O&M.

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TABLE 3–13 (Continued)
GROUND WATER PROCESS OPTION SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

● Representative Process Option

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
Extraction/ Treatment/ Discharge (continued)	Biological/Physical/ Chemical Organic Treatment	Bioreactor	Proven effective for removal of organics, phenols; ineffective for inorganics.	Fairly easily implemented; not as widely available as other treatment technology.	Moderate capital; moderate O&M.
		PACT	Effective for organic compounds, including chlorinated organics; provides an extended residence time for more effective treatment; proven for treatment of leachates.	Fairly easily implemented; not as widely available as other treatment technology.	Moderate to high capital; moderate O&M.
		Air Stripping	● Generally effective for volatile organics.	Readily implemented; may require treatment of off–gases.	Moderate capital; low O&M.
		Steam Stripping	Effective for volatile organics; more effective than air stripping in treating organics of lesser volatility.	Fairly easily implemented; may require treatment of off–gases.	Moderate to high capital; moderate O&M.
		Carbon Adsorption	Effective for low solubility organics.	Readily implemented; requires on– or off–site regeneration of carbon.	Moderate capital; low to moderate O&M.
		Resin Adsorption	Effective for organic removal.	Prior to implementation, identification of resin applicable to contaminants in ground water is required.	High capital; moderate O&M.
		UV Oxidation	● Effective for treatment of volatiles and semi–volatiles; no emissions or waste by–products produced.	Readily implemented.	Moderate to high capital; moderate O&M.

TABLE 3-13 (Continued)
GROUND WATER PROCESS OPTION SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

● Representative Process Option

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
Extraction/ Treatment/ Discharge (continued)	Inorganic Treatment	Ion Exchange	Effective for inorganic removal; requires selection of resin suitable for contaminants of concern.	Fairly easily implemented; operation is relatively simple.	Moderate capital; moderate O&M.
		Precipitation	● Effective for removal of dissolved inorganics; precipitate must be disposed of.	Readily implemented.	Low to moderate capital; moderate O&M.
		Membrane Microfiltration	● Effective in removing undissolved heavy metals, including very small colloidal particles; produces less sludge since no chemicals are added during treatment; treatability studies required to demonstrate effectiveness of technology.	Can be manufactured as a mobile system.	Moderate capital, moderate O&M.
		Filtration	Effective in removing filterable heavy metals.	Readily implemented.	Moderate capital, moderate O&M.
		Electrochemical	Effective in producing metal hydroxide precipitates of such inorganic species as arsenic, cadmium, zinc and copper.	Newly developing technology; may not be widely available; more complicated than other inorganic treatment systems.	Moderate capital, moderate O&M.
	Discharge	Ground Water	Effective with permeable soils and relatively low flow rates.	Requires construction of a recharge system; requires compliance with discharge criteria; location of recharge system will need to consider presence of waste materials over majority of site and potential presence of cap or containment features; discharge to lower portion of aquifer hampered by presence of low–conductivity silty soils.	Moderate capital; low to moderate O&M.
		Surface Water	● Effective for discharge of treated ground water.	Requires installation of a discharge pipe; requires compliance with discharge criteria.	Moderate capital; low O&M.
		Sanitary Sewer/ POTW	Effective for discharge of treated ground water.	Requires construction of discharge pipe to tie into existing sewer system; requires compliance with discharge criteria.	High capital; high discharge fees.

TABLE 3-14
SEDIMENT PROCESS OPTION SCREENING
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

● Representative Process Option

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
No Action	None	Not Applicable	● Is not effective in addressing potential environmental risks posed by contaminated sediments.	No implementation is required.	No cost.
Institutional Control	Site Use Restrictions	Deed Restrictions	Limits disturbance of existing contamination; due to anthropogenic activities does not address environmental forces (e.g. storms) which could disturb sediments.	Requires appropriate legal authority.	Low capital cost.
		Long – Term Monitoring	● Effective in identifying changes in sediment quality which could pose additional risks to the environment.	Easily implemented.	Low capital cost; low to moderate maintenance cost.
Containment	Capping	Stone	● Effective in supporting epibenthic organisms and in preventing exposures to benthic organisms; addresses environmental risks and provides erosion protection along shoreline.	Fairly easily implemented.	Moderate capital; low maintenance.

TABLE 3-15
SITE 09 – ALLEN HARBOR LANDFILL

TECHNOLOGIES AND PROCESS OPTIONS WHICH PASSED SCREENING

Soil/Waste

No Action
- No Action

Institutional Controls
- Deed Restrictions
- Fencing

Surface Controls
- Grading
- Revegetation

Containment
- ● Native Soil Cap
- RCRA Subtitle C Hybrid Cap
- RCRA Subtitle C Landfill Cap

Sediment

No Action
- No Action

Institutional Controls
- Deed Restrictions
- Long – Term Monitoring

Containment
- Stone

Ground Water/Leachate

No Action
- ● No Action

Institutional Controls
- ● Long – Term Monitoring
- ● Deed Restrictions

Containment
- ● Capping
- Slurry Wall
- ● Sheet Piling

Extraction/Treatment/Discharge
- ● Extraction Wells
- Bioreactor
- PACT
- ● Air Stripping
- Steam Stripping
- Carbon Adsorption
- Resin Adsorption
- ● UV Oxidation
- Ion Exchange
- ● Precipitation
- ● Membrane Microfiltration
- Filtration
- Electrochemical
- Discharge to Ground Water
- ● Discharge to Surface Water
- Sanitary Sewer/POTW Discharge

● – Process Technology Used to Formulate Remedial Alternatives

TABLE 3-16
SITE 09 – ALLEN HARBOR LANDFILL
ALTERNATIVES UNDERGOING DETAILED ANALYSIS

Soil/Waste	Ground Water/Leachate
<u>Alternative S/W-1</u> No Action <u>Alternative S/W-2</u> Limited Action (Institutional Controls) A. Fencing/Deed Restrictions <u>Alternative S/W-3</u> Containment (including Grading/ Revegitation) A. Native Soil Cap B. RCRA Subtitle C Hybrid Cap C. RCRA Subtitle C Landfill Cap	<u>Alternative GW-1</u> No Action <u>Alternative GW-2</u> Limited Action (Institutional Controls) A. Long – Term Monitoring B. Deed Restrictions <u>Alternative GW-3</u> Containment A. Capping B. Sheet Piling <u>Alternative GW-4</u> Treatment A. Extraction (Extraction Wells) B. Air Stripping C. UV Oxidation D. Precipitation E. Membrane Microfiltration F. Discharge to Surface Water
Sediment <u>Alternative SD-1</u> No Action <u>Alternative SD-2</u> Limited Action (Institutional Controls) A. Long – Term Monitoring <u>Alternative SD-3</u> Containment A. Stone	

TABLE 4-1
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-1 - NO ACTION
ALTERNATIVE S/W-2 - LIMITED ACTION
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Soils/Surfaces--				
	Toxic Substances Control Act (40 CFR 761.125)	Relevant and Appropriate	Establishes PCB cleanup levels for soils and solid surfaces.	Since these alternatives do not address PCBs in soils, this ARAR is not met.
	Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02)	To Be Considered	Sets forth an interim soil cleanup level for lead at 500 to 1000 ppm.	Since these alternatives do not address lead in soils, compliance with this guidance is not achieved.
STATE				
Soils/Surfaces--				
	Lead Soil Cleanup Standard (Guidance)	To Be Considered	RIDEM and the Rhode Island Department of Health-Risk Assessment consider a safe lead level in soil (total) to be under 300 ppm.	Since these alternatives do not address lead in soils, this guidance is not met.
	RI Hazardous Waste Management Act of 1987 (RIGL 23-19.1 et seq.) Rules and Regulations for Hazardous Waste Management	Relevant and Appropriate	Defines Type 6 - Extremely hazardous waste as including wastes which contain PCBs at a concentration of 50 ppm or greater or showing 10 $\mu g/100\ cm^2$ or greater as measured by a standard wipe test.	Relevant and appropriate to the development of PRGs for soil. Since these alternatives do not address PCBs in soils, this ARAR is not met.
	Rules and Regulations for Solid Waste Management Facilities	Relevant and Appropriate	Defines solid waste as including any soil, debris or other material with a concentration of PCBs of 10 ppm or greater or containing 2 $\mu g/100\ cm^2$ or greater as measured by a standard wipe test.	Relevant and appropriate to the development of PRGs for soil. Since these alternatives do not address PCBs in soils, this ARAR is not met.

TABLE 4-2
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-1 - NO ACTION
ALTERNATIVE S/W-2 - LIMITED ACTION
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Wetlands/Water Resources--				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Since these alternatives do not impact coastal or on-shore wetland areas, they meet this ARAR.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredge or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Filling a Navigable Water	Applicable	Prohibits the discharge of dredged or fill material to a water of the United States if there is a practicable alternative which poses less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	Since these alternatives do not impact wetlands and and waters, or cause degradation of water, they meet this ARAR.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making process which may impact water bodies, including wetlands. Measures to prevent, mitigate or compensate for losses of fish and wildlife will be given due consideration whenever a modification of a water body is proposed.	If the implementation of a remedial action results in an impact to a water body, consultation with U.S. Fish and Wildlife Service, RIDEM, and other federal and state agencies involved in fish and wildlife matters is required. ARAR for fencing if fencing extends into Allen Harbor.

TABLE 4-2 (continued)
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-1 - NO ACTION
ALTERNATIVE S/W-2 - LIMITED ACTION
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Coastal Zones--	Coastal Zone Management Act (16 USC Section 1451 et seq.)	Applicable	Regulates activities affecting the coastal zone including lands thereunder and adjacent shoreline.	For remedial actions in a coastal zone, requires determination that all activities are consistent to the maximum extent practicable with State Coastal Zone Management Plan. ARAR for fencing.
STATE				
Wetlands--	Rhode Island Wetlands Laws (RIGL 2-1-18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh-water Wetlands Act - as amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Since these alternatives do not impact, a wetland area, they meet this ARAR.
Coastal Zone--	Rhode Island Coastal Resources Management Law, (RIGL, Title 46, Chapter 23) and Regulations	Applicable	Creates Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources.	Since Allen Harbor Landfill is located in a coastal area, the Navy will coordinate with the Rhode Island Coastal Resources Management Council and will ensure that all actions are consistent, to the maximum extent practicable, with the Coastal Zone Management Plan. ARAR for fencing.

TABLE 4-3
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-2 - LIMITED ACTION
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
FEDERAL				
Drainage/ Discharge	Clean Water Act (40 CFR 122-125) National Pollutant Discharge Elimination System (NPDES) Permit Requirements	Applicable	Permits contain applicable effluent standards (i.e. technology- and/or water quality-based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste from industrial facilities.	Any storm water drainage improvements would be designed to provide compliance with these regulations and drainage would be monitored in compliance with these regulations.
Fencing	Migratory Bird Treaty Act (16 U.S.C. 703-712)	Applicable	Prohibits hunting, possessing, killing, or capturing of migratory birds, birds in danger of extinction, and those birds' eggs or nests.	Since construction activities during the breeding season may "take" birds or their nests, actions must be taken to avoid destroying nests during breeding season.
STATE				
Drainage/ Discharge	RI Water Pollution Control Act			
	• RI Water Quality Regulations for Water Pollution Control (RIGL 46-12, et seq.) RI Water Quality Standards	Applicable	Establishes general requirements and effluent limits for discharge to area waters.	In compliance with these regulations, RIPDES requirements pertaining to storm water discharges or treatment system discharges would be met.
	• Regulations for the RI Pollutant Discharge Elimination System (RIPDES) (RIGL 46-12, et seq.)	Applicable	Permits contain applicable effluent (i.e. technology - based and/or water quality - based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste.	Storm water discharge improvements or ground water treatment systems would be designed to provide compliance with these regulations and drainage/discharge would be monitored in compliance with these regulations.

TABLE 4-4
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-3 – CONTAINMENT
OPTION S/W-3A – NATIVE SOIL CAP
OPTION S/W-3B – RCRA HYBRID CAP
OPTION S/W-3C – RCRA LANDFILL CAP
SITE 09 – ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL Soils/Surfaces--				
	Toxic Substances Control Act (40 CFR 761.125)	Relevant and Appropriate	Establishes PCB cleanup levels for soils and solid surfaces.	Applicable to spills of materials containing PCBs at concentrations of 50 ppm or greater that occurred after May 4, 1987. While not applicable to Site 09, these requirements are relevant and appropriate. By preventing exposures to PCBs in the future, this ARAR is met.
	Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02)	To Be Considered	Sets forth an interim soil cleanup level for lead at 500 to 1000 ppm.	Will be considered with respect to soil lead contamination. By preventing exposures to lead in the future, this guidance is met.
STATE Soils/Surfaces--				
	Lead Soil Cleanup Standard (Guidance)	To Be Considered	RIDEM and the Rhode Island Department of Health-Risk Assessment consider a safe lead level in soil (total) to be under 300 ppm.	To be considered with respect to lead soil contamination. By preventing exposures to lead in the future, this guidance is met.
	RI Hazardous Waste Management Act of 1987 (RIGL 23-19.1 et seq.) Rules and Regulations for Hazardous Waste Management	Relevant and Appropriate	Defines Type 6 – Extremely hazardous waste as including wastes which contain PCBs at a concentration of 50 ppm or greater or showing 10 $\mu g/100\ cm^2$ or greater as measured by a standard wipe test.	Relevant and appropriate to the development of PRGs for soil. By preventing exposures to PCBs in the future, this guidance is met.
	Rules and Regulations for Solid Waste Management Facilities	Relevant and Appropriate	Defines solid waste as including any soil, debris or other material with a concentration of PCBs of 10 ppm or greater or containing 2 $\mu g/100\ cm^2$ or greater as measured by a standard wipe test.	Relevant and appropriate to the development of PRGs for soil. By preventing exposures to PCBs in the future, this guidance is met.

TABLE 4-5
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-3 - CONTAINMENT
OPTION S/W-3A - NATIVE SOIL CAP
OPTION S/W-3B - RCRA HYBRID CAP
OPTION S/W-3C - RCRA LANDFILL CAP
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
<u>FEDERAL</u>				
Wetlands/Water Resources--				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Will be applicable if cap construction or shoreline protection impact coastal or on-shore wetland areas.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredge or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Filling a Navigable Water	Applicable	Prohibits the discharge of dredged or fill material to a water of the United States if there is a practicable alternative which poses less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	Applicable if cap construction or shoreline protection impact wetlands and waters, or cause degradation of water. If construction cannot be limited to within toeprint of existing landfill, mitigation of impacted wetlands may be required.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making process which may impact water bodies, including wetlands. Measures to prevent, mitigate or compensate for losses of fish and wildlife will be given due consideration whenever a modification of a water body is proposed.	ARAR for cap construction if it impacts Allen Harbor, and for shoreline protection.

TABLE 4–5 (continued)
FEDERAL AND STATE LOCATION–SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W–3 – CONTAINMENT
OPTION S/W–3A – NATIVE SOIL CAP
OPTION S/W–3B – RCRA HYBRID CAP
OPTION S/W–3C – RCRA LANDFILL CAP
SITE 09 – ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Coastal Zones--				
	Coastal Zone Management Act (16 USC Section 1451 et seq.)	Applicable	Regulates activities affecting the coastal zone including lands thereunder and adjacent shoreline.	ARAR for cap construction and shoreline protection.
STATE				
Wetlands--				
	Rhode Island Wetlands Laws (RIGL 2–1–18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh–water Wetlands Act – as amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Will be applicable if cap construction or shoreline protection impact a freshwater wetland area.
Coastal Zone--				
	Rhode Island Coastal Resources Management Law, (RIGL, Title 46, Chapter 23) and Regulations	Applicable	Creates Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources.	Since Allen Harbor Landfill is located in a coastal area, the Navy will coordinate with the Rhode Island Coastal Resources Management Council and will ensure that all actions are consistent, to the maximum extent practicable, with the Coastal Zone Management Plan. ARAR for capping and shoreline protection.

TABLE 4-6
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-3 - CONTAINMENT
OPTION S/W-3A - NATIVE SOIL CAP
OPTION S/W-3B - RCRA HYBRID CAP
OPTION S/W-3C - RCRA LANDFILL CAP
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
FEDERAL				
Drainage/ Discharge	Clean Water Act (40 CFR 122-125) National Pollutant Discharge Elimination System (NPDES) Permit Requirements	Applicable	Permits contain applicable effluent standards (i.e. technology- and/or water quality-based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste from industrial facilities.	Any storm water drainage improvements would be designed to provide compliance with these regulations and drainage would be monitored in compliance with these regulations.
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	Relevant and Appropriate	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC will be relevant and appropriate to the development of discharge criteria for storm water, as described above.
Capping/ Monitoring	Migratory Bird Treaty Act (16 U.S.C. 703-712)	Applicable	Prohibits hunting, possessing, killing, or capturing of migratory birds, birds in danger of extinction, and those birds' eggs or nests.	Since construction activities during the breeding season may "take" birds or their nests, actions must be taken to avoid destroying nests during breeding season.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredged or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Wetland Filling	Applicable	Prohibits the discharge of dredged or fill material to waters of the United States unless no other practical alternatives are available which pose less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	If cap construction cannot be limited to areas within the toeprint of the existing landfill, mitigation of any impacted wetlands may be required.

TABLE 4-6 (continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-3 - CONTAINMENT
OPTION S/W-3A - NATIVE SOIL CAP
OPTION S/W-3B - RCRA HYBRID CAP
OPTION S/W-3C - RCRA LANDFILL CAP
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Capping/ Monitoring (cont.)	RCRA (40 CFR 264) Subtitle C Requirements:	Relevant and Appropriate	Outlines specifications and standards for design, operation, closure and monitoring of performance for hazardous waste storage, treatment and disposal facilities.	Substantive RCRA requirements will be met and adhered to on-site if appropriate to capping.
	• 40 CFR 264.90-254.101 Subpart F - Ground Water Protection	Relevant and Appropriate	Ground water monitoring/corrective action requirements; dictates adherence to MCLs unless ACLS are appropriate and establishes points of compliance.	Monitoring standards will be met.
	• 40 CFR 264.110-118 Subpart G - Closure/Post Closure Requirements	Relevant and Appropriate	Establishes requirements for the closure and long-term management of a hazardous disposal facility.	Relevant and appropriate standards and requirements will be met.
	• 40 CFR 264.303-264.310; Subpart N - Landfill Requirements	Relevant and Appropriate	Placement of cap over hazardous waste requres a cover designed and constructed to comply with regulations. Installation of final cover to provide long-term minimization of infiltration. Restricts post-closure use of property as necessary to prevent damage to cover.	Cap designs meet relevant and appropriate requirements. Option S/W-3C exceeds relevant and appropriate requirements.
	• RCRA Proposed Rule 52 FR 8712, 53 FR 51446 Proposed Amendments for Landfill Closures	To Be Considered	Provides an option for the application of alternate closure and post-closure requirements based on a consideration of site-specific conditions including exposure pathways of concern.	Cap and post-closure monitoring designs take into account exposure pathways of concern.
	• EPA Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments (EPA 530-SW-89-047)	To Be Considered	EPA Technical Guidance for landfill covers. Presents recommended technical specifications for multilayer landfill cover design.	These standards were considered in development of the cap designs.

TABLE 4-6 (continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-3 - CONTAINMENT
OPTION S/W-3A - NATIVE SOIL CAP
OPTION S/W-3B - RCRA HYBRID CAP
OPTION S/W-3C - RCRA LANDFILL CAP
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air	Clean Air Act (40 CFR 60) New Source Performance Standards (NSPS) Proposed Subpart WWW 56 FR 24468-24528 (5/30/91)	To Be Considered	Requires Best Demonstrated Technology (BDT) for new sources, and sets emissions limitations. Proposed Subpart WWW sets a performance standard for non-methane organic compounds (NMOC) emissions of 150 Mg/yr (167 tpy) for existing municipal solid waste landfills.	These standards should be considered if a landfill gas management system is required under Options S/W-3B or S/W-3C.
	Clean Air Act (40 CFR 61) National Emissions Standards for Hazardous Pollutants (NESHAP)	To Be Considered	Establishes emissions limitations for hazardous air pollutants and sets forth regulated sources of those pollutants.	Although EPA has not promulgated final Maximum Achievable Control Technology (MACT) standards for municipal landfills, the lead agency should use air control technology to control emissions of hazardous air pollutions. MACT standards prescribe technology that is used by the best 12% of industries in the source category.
	Clean Air Act, Section 5 171 through 178, 42 USC §§ 7471-7478 (Requirements for Non-Attainment Areas)	Applicable or Relevant and Appropriate (Depending on Modelling Results)	RI has adopted State Implementation Plan (SIP) requirements approved and enforcable by EPA which meet the New Source Review (NSR) requirement of the CAA. These provisions require that new or modified major sources of VOCs defined as a source which has the potential to emit 50 tpy install equipment to meet Lowest Available Emissions Rate (LAER), which is set on a case-by-case basis and is either the most stringent emissions limitation contained in any SIP for that category or source or the most stringent emissions limitation which is achieved for the source. NSR requirements apply to non-attainment pollutants, which are VOCs and NO_x in RI.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels and on the need to be protective of human health and the environment.

TABLE 4-6 (continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-3 – CONTAINMENT
OPTION S/W-3A – NATIVE SOIL CAP
OPTION S/W-3B – RCRA HYBRID CAP
OPTION S/W-3C – RCRA LANDFILL CAP
SITE 09 – ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	Clean Air Act, Section 5 160 through 169A – Prevention of Significant Deterioration Provisions	Applicable or Relevant and Appropriate (Depending on Modelling Results)	RI has adopted SIP requirements approved and enforceable by EPA which meet the Prevention of Significant Deterioration (PSD) requirements of the CAA. These provisions require that new or modified major sources of VOCs, defined as a source which has the potential to emit 25 tons/year, install equipment to meet Best Available Control Technology (BACT). PSD requirements apply to attainment pollutants, which are SO2, CO, lead and particulates in Rhode Island.	Monitoring will be conducted under Options S/W-3B and S/W-3C to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels.
STATE Drainage/ Discharge	RI Water Pollution Control Act			
	• RI Water Quality Regulations for Water Pollution Control (RIGL 46-12, et seq.) RI Water Quality Standards	Applicable	Establishes general requirements and effluent limits for discharge to area waters.	In compliance with these regulations, RIPDES requirements pertaining to storm water discharges or treatment system discharges would be met.
	• Regulations for the RI Pollutant Discharge Elimination System (RIPDES) (RIGL 46-12, et seq.)	Applicable	Permits contain applicable effluent (i.e. technology – based and/or water quality – based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste.	Storm water discharge improvements would be designed to provide compliance with these regulations and drainage/discharge would be monitored in compliance with these regulations.
Capping/ Monitoring	RI Refuse Disposal Law Rules and Regulations for Solid Waste Management Facilities	Relevant and Appropriate	Rules and regulations intended to minimize environmental hazards associated with the operation of solid waste transfer, resource recovery, and disposal facilities.	Closure design criteria and ground water monitoring requirements may be relevant and apppropriate if a RCRA hybrid cap is considered.

TABLE 4-6 (continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-3 - CONTAINMENT
OPTION S/W-3A - NATIVE SOIL CAP
OPTION S/W-3B - RCRA HYBRID CAP
OPTION S/W-3C - RCRA LANDFILL CAP
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Capping/ Monitoring (cont.)	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.) Hazardous Waste Management Rules and Regulations	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage and disposal.	Substantive requirements applicable to closure will be met and adhered to on-site.
	• Section 7	Relevant and Appropriate	Restricts location, design, construction, and operation of landfills from endangering ground water, wetlands or floodplains.	Remedial actions will be designed so as to prevent contamination of ground water, wetlands, or floodplains.
	• Section 8	Relevant and Appropriate	Outlines requirements for ground water protection, general waste analysis, security procedures, inspections and safety.	Remedial actions will comply with substantive portions of this section applicable to landfill closure.
	• Section 9	Relevant and Appropriate	Outlines operational requirements for treatment, storage and disposal facilities.	Remedial actions, including ground water monitoring, will comply with substantive portions of this section applicable to landfill closure.
	• Section 10	Relevant and Appropriate	Outlines design and operations requirements for land disposal facilities, including landfills.	Remedial actions will meet all non-location specific requirements of this section applicable to landfill closure.

TABLE 4-6 (continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-3 - CONTAINMENT
OPTION S/W-3A - NATIVE SOIL CAP
OPTION S/W-3B - RCRA HYBRID CAP
OPTION S/W-3C - RCRA LANDFILL CAP
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air	RI Clean Air Act (RIGL, Title 23, Chapter 23) General Air Quality and Air Emissions Requirements • RI Air Pollution Control Regulations, RI Dept. of Health, Div. of Air Pollution Control, effective 8/2/67, most recently amended 5/20/91			
	- Regulation No. 1 - Visible Emissions	Applicable	No air contaminant emissions will be allowed for more than 3 minutes in any one hour which are greater than or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulation.
	- Regulation No. 5 - Fugitive Dust	Applicable	Requires that reasonable precaution be taken to prevent particulate matter from becoming airborne.	On-site remedial actions will use good industrial practices to prevent particulate matter from becoming airborne.
	- Regulation No. 7 - Emissions Detrimental to Person or Property	Applicable	Prohibits emissions of contaminants which may be injurious to human, plant or animal life or cause damage to property or which reasonably interferes with the enjoyment of life and property.	All emissions will meet this requirement or gas treatment will be required.
	- Regulation No. 9 - Approval to Construct, Install, Modify or Operate	Applicable	Establishes guidelines for the construction, installation, modification or operation of potential air emission units. Establishes permissible emission rates for some contaminants.	Technologies involving construction, installation, modification or operation of air emission units will meet these requirements.
	- Regulation No. 15 - Control of Organic Solvent Emissions	Applicable	Limits the amount of organic solvents emitted to the atmosphere.	If emissions exceed limits in this regulation, emission controls will be designed and implemented to meet these requirements.

TABLE 4-6 (continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S/W-3 - CONTAINMENT
OPTION S/W-3A - NATIVE SOIL CAP
OPTION S/W-3B - RCRA HYBRID CAP
OPTION S/W-3C - RCRA LANDFILL CAP
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	- Regulation No. 17 - Odors	Applicable	Prohibits the release of objectionable odors across property lines.	No remedial action or air emissions will emit objectionable odors beyond the facility boundary, as practicable.
	- Regulation No. 22 - Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels or acceptable ambient levels with LAER, as set in the regulation.	If air emissions contain regulated substances, air emissions control equipment will be used as necessary to meet these standards.

TABLE 4-7
COMPARISON AMONG SOIL/WASTE ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative S/W-1 - No Action	Least protective alternative; No control of potential exposures to site-related contamination is provided; Does not comply with chemical-specific ARARs; Not effective in the short-term or long-term
Alternative S/W-2 - Limited Action	Provides a limited degree of protection of human health by limiting potential exposures to site contaminants through site fencing and deed restrictions; Provides no additional protection of the environment; Does not comply with chemical-specific ARARs/TBCs; Effective in the short-term but does not provide the long-term effectiveness offered by Alternative S/W-3
Alternativ S/W-3 - Containment Alternative	Provides the greatest degree of long-term protection of human health and the environment through the minimization of potential exposures to the site contaminants and by minimizing the potential migration of contaminants due to erosion
Option S/W-3A - Native Soil Cap	Provides protection of human health and the environment by providing a physical barrier to exposures to surficial contamination; Complies with chemical-specific, action-specific and location-specific ARARs/TBCs; Some increased short-term risks would result during implementation; Would be effective in the long-term
Option S/W-3B - RCRA Subtitle C Hybrid Cap	Provides protection of human health and the environment by providing a physical barrier to exposures to surficial contamination; Would provide greater protection against leachate seeps from the side slopes of the landfill than Option S/W-3A; Complies with chemical-specific, action-specific and location-specific ARARs/TBCs; Some increased short-term risks would result during implementation; Would be effective in the long-term
Option S/W-3C - RCRA Subtitle C Landfill Cap	Provides protection of human health and the environment by providing a physical barrier to exposures to surficial contamination; Combined soil and synthetic layers would provide additional protection against infiltration of precipitation into the landfill but are not considered to offer a significantly greater degree of protection than Option S/W-3B; Would provide protection against leachate seeps from the side slopes of the landfill; Complies with chemical-specific, action-specific and location-specific ARARs/TBCs; Cap design would exceed relevant and appropriate RCRA hazardous waste landfill closure requirements; Some increased short-term risks would result during implementation; Would be effective in the long-term

TABLE 4-8
COMPARISON AMONG SOIL/WASTE ALTERNATIVES
COMPLIANCE WITH ARARs/TBCs
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE, RI

ACTION	CHEMICAL-SPECIFIC	LOCATION-SPECIFIC	ACTION-SPECIFIC
Alternative S/W-1 – No Action	Does not meet criteria	Meets criteria; Involves no actions which impact coastal or wetland areas	Not applicable
Alternative S/W-2 – Limited Action	Does not meet criteria	Implementation of fencing would comply with wetland and coastal zone criteria	Storm water discharge monitoring would be conducted in accordance with NPDES and RIPDES requirements
Alternative S/W-3 – Containment Alternative	Preventing exposures to PCBs and lead in soils in the future would meet criteria	Implementation of construction activities would comply with criteria (i.e. wetland and coastal zone requirements); Mitigation of any impacted wetlands may be required	Would comply with criteria applicable to storm water discharge, venting, and relevant and appropriate landfill closure requirements
Option S/W-3A – Native Soil Cap	See S/W-3	See S/W-3	Native soil cap would meet definition of a RCRA hybrid cap in compliance with relevant and appropriate RCRA requirements
Option S/W-3B – RCRA Subtitle C Hybrid Cap	See S/W-3	See S/W-3	Single-barrier cap would comply with relevant and appropriate RCRA requirements as well as RIDEM solid waste landfill closure requirements
Option S/W-3C – RCRA Subtitle C Landfill Cap	See S/W-3	See S/W-3	Double-barrier cap would meet state and federal ARARs pertaining to hazardous waste landfill closure; Would exceed relevant and appropriate RCRA requirements

TABLE 4-9
COMPARISON AMONG SOIL/WASTE ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative S/W-1 - No Action	Existing site-related risks to human health and the environment remain; No controls implemented to limit potential exposures to site contamination; Requires five-year review
Alternative S/W-2 - Limited Action	Relies on institutional controls to limit human exposures to site contamination; Access to contamination along shoreline may be difficult to restrict; Requires five-year review
Alternative S/W-3 - Containment Alternative	Reduces the potential risks associated with direct contact with site-related contaminants but some residual risk would remain since the source (the landfill) is not treated or removed; Containment options are expected to be relatively reliable in the long-term although periodic maintenance may be required; Requires five-year review
Option S/W-3A - Native Soil Cap	Containment of contamination is provided through the physical barrier of a soil cap but residual risk remains due to the continued presence of the landfilled wastes; Effective in the long-term in limiting potential physical exposures to surficial contamination but is not as effective as Options S/W-3B and S/W-3C in limiting potential infiltration of precipitation or leachate seeps; Would support re-establishment of existing vegetation and habitat; Requires five-year review
Option S/W-3B - RCRA Subtitle C Hybrid Cap	Containment of contamination is provided through the physical barrier of a hybrid single-barrier cap but residual risk remains due to the continued presence of the landfilled wastes; Effective and reliable in the long-term in limiting potential physical exposures to surficial contamination as well as minimizing infiltration of precipitation and leachate seeps; Potential generation of landfill gas, which could impair the effectiveness of the cap, would require further investigation prior to design; Could not support existing vegetation and habitat; Requires five-year review
Option S/W-3C - RCRA Subtitle C Landfill Cap	Containment of contamination is provided through the physical barrier of the RCRA double-barrier cap but residual risk remains due to the continued presence of the landfilled wastes; Effective and reliable in the long-term in limiting potential physical exposures to surficial contamination as well as minimizing infiltration of precipitation and leachate seeps; Potential generation of landfill gas, which could impair the effectiveness of the cap, would require further investigation prior to design; Could not support existing vegetation and habitat; Requires five-year review

TABLE 4-10
COMPARISON AMONG SOIL/WASTE ALTERNATIVES
REDUCTION IN TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative S/W-1 - No Action	Provides no reduction in toxicity, mobility or volume through treatment
Alternative S/W-2 - Limited Action	Provides no treatment of site contamination and therefore no associated reduction in contaminant toxicity, mobility, or volume; Site access restrictions would limit the potential human exposure pathways associated with current or future site use
Alternativ S/W-3 - Containment Alternative	Provides no treatment of site contamination and therefore no associated reduction in contaminant toxicity, mobility, or volume; Reductions in contaminant mobility due to containment features would limit erosion of surficial contaminants and/or infiltration of precipation through the waste materials to various degrees depending on the selected capping option
Option S/W-3A - Native Soil Cap	Provides no treatment of site contamination and therefore no associated reduction in contaminant toxicity, mobility, or volume; However, reductions in contaminant mobility associated with surficial erosion would be achieved due to containment features
Option S/W-3B - RCRA Subtitle C Hybrid Cap	Provides no treatment of site contamination and therefore no associated reduction in contaminant toxicity, mobility, or volume; While no treatment is provided, a reduction in the contaminant mobility associated with surficial erosion and leachate seeps would be achieved
Option S/W-3C - RCRA Subtitle C Landfill Cap	Provides no treatment of site contamination and therefore no associated reduction in contaminant toxicity, mobility, or volume; While no treatment is provided, a reduction in the contaminant mobility associated with surficial erosion and leachate seeps would be achieved

TABLE 4-11
COMPARISON AMONG SOIL/WASTE ALTERNATIVES
SHORT-TERM EFFECTIVENESS
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative S/W-1 - No Action	No remedial activities conducted; Therefore, no short-term risks result; Remedial response objectives not achieved
Alternative S/W-2 - Limited Action	Minimal short-term risks associated with fence construction; Short implementation time frame; Remedial response objectives not achieved
Alternative S/W-3 - Containment Alternative	Due to site disturbance required to implement Alternative S/W-3, some increased short-term risks to workers could result; Personnel protective equipment would minimize risks; Erosion containment measures could be used to minimize environmental impacts; Off-site impacts of construction would be expected to be minimal; Remedial response objectives achieved
Option S/W-3A - Native Soil Cap	See S/W-3; Estimated implementation time frame is one year
Option S/W-3B - RCRA Subtitle C Hybrid Cap	See S/W-3; Estimated implementation time frame is one to two years
Option S/W-3C - RCRA Subtitle C Landfill Cap	See S/W-3; Estimated implementation time frame is two years

TABLE 4-12
COMPARISON AMONG SOIL/WASTE ALTERNATIVES
IMPLEMENTABILITY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative S/W-1 – No Action	Requires no implementation other than a five-year review; Would not limit the implementation of other remedial actions
Alternative S/W-2 – Limited Action	Fencing construction easily implemented; Deed restrictions would have to be incorporated in the base closure property transfer process; Would contradict future site use specified under Base Reuse Plan; Would not limit the implementation of other remedial actions
Alternative S/W-3 – Containment Alternative	Most difficult to implement with respect to constructability; Site preparation would entail clearing of site vegetation and regrading; Some movement and recompaction of existing waste materials would be required; Construction activities associated with shoreline protection may be difficult to implement; Containment features could be impacted if future remedial actions are required; Could support future site use specified under Base Reuse Plan
Option S/W-3A – Native Soil Cap	Relatively easy to implement; Employs commonly used equipment and construction materials and techniques; Not a significant barrier to the implementation of other remedial actions
Option S/W-3B – RCRA Subtitle C Hybrid Cap	More difficult to implement than Option S/W-3A, requiring special equipment and materials for geomembrane installation and extra care in placement of overlying cap materials to prevent puncture of the geomembrane; Due to existing steep slope along Allen Harbor and the potential slope stability problems associated with the interface between soil layers and smooth geomembrane materials, cap construction could be difficult; Option S/W-3B could be combined with a stone revetment or sheet piling to provide shoreline protection; Presence of cap could complicate implementation of other remedial actions
Option S/W-3C – RCRA Subtitle C Landfill Cap	Most difficult option to implement, requiring special equipment and materials for geomembrane installation and extra care in placement of overlying cap materials to prevent puncture of the geomembrane; Location of sufficient volumes of low permeability material for barrier layer may be difficult; Due to existing steep slope along Allen Harbor and the potential slope stability problems associated with the interface betweeen soil layers and smooth geomembrane materials, cap construction could be difficult; Option S/W-3C could be combined with a stone revetment or sheet piling to provide shoreline protection; Presence of cap could complicate implementation of other remedial actions

TABLE 4-13
COMPARISON AMONG SOIL/WASTE ALTERNATIVES
COST
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT WORTH O&M COST [1]	TOTAL PRESENT WORTH [2]
Alternative S/W-1 - No Action	--	--	--	Nominal [3]
Alternative S/W-2 - Limited Action	$61,000	$19,000	$290,000	$420,000
Alternative S/W-3 - Containment Alternative				
Option S/W-3A - Native Soil Cap	$1,900,000	$20,000	$300,000	$2,700,000
Option S/W-3B - RCRA Subtitle C Hybrid Cap	$2,700,000	$24,000	$370,000	$3,800,000 [4]
Option S/W-3C - RCRA Subtitle C Landfill Cap	$4,100,000	$24,000	$370,000	$5,400,000 [4]

[1] - Based on 5% discount rate.
[2] - Includes 20% contingency on all components.
[3] - The only cost associated with the implementation of Alternative S/W-1 would be that associated with conducting a five-year review of the no action decision.
[4] - Additional costs could be incurred if landfill gas treatment is required.

TABLE 4-14
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-1 - NO ACTION
ALTERNATIVE GW-2 - LIMITED ACTION
OPTION GW-2A - LONG TERM MONITORING
OPTION GW-2B - DEED RESTRICTIONS
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL Ground Water--				
	Resource Conservation and Recovery Act, Subpart F (40 CFR 264.94) Ground Water Protection Standards, Alternate Concentration Limits	Relevant and Appropriate	Allows for the development of alternate concentration limits (ACLs) for facilities which treat, store or dispose of hazardous waste when the characteristics of the ground water (e.g., high salinity) limit the application of Maximum Contaminant Levels or health-based criteria. Exposure-based ACLs may be developed which take into consideration potential adverse effects on ground water quality and hydraulically-connected surface water quality.	Ground water alternate concentration limits, although currently undeveloped, may be relevant and appropriate to the development of site-specific remediation levels.
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	To be Considered	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC, with modification, may be relevant and appropriate to the development of PRGs for ground water based on the potential discharge of ground water to surface water that is used for fishing.
STATE Ground Water --				
	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	To be determined	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	WQS, with modification, may be relevant and appropriate to the development of PRGs for ground water based on the potential discharge of ground water to surface water that is used for fishing.

TABLE 4–15
FEDERAL AND STATE LOCATION–SPECIFIC ARARs AND TBCs
ALTERNATIVE GW–1 – NO ACTION
ALTERNATIVE GW–2 – LIMITED ACTION
OPTION GW–2A – LONG TERM MONITORING
OPTION GW–2B – DEED RESTRICTIONS
SITE 09 – ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
<u>FEDERAL</u>				
Wetlands/Water Resources– –				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long– and short–term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Since these alternatives do not impact coastal or on–shore wetland areas, they meet this ARAR.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredge or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Filling a Navigable Water	Applicable	Prohibits the discharge of dredged or fill material to a water of the United States if there is a practicable alternative which poses less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	Since these alternatives do not involve the discharge of dredged or fill material, they meet this ARAR.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision–making process which may impact water bodies, including wetlands. Measures to prevent, mitigate or compensate for losses of fish and wildlife will be given due consideration whenever a modification of a water body is proposed.	Since these alternatives do not involve modification of a water body, they meet this ARAR.

TABLE 4–15(Continued)
FEDERAL AND STATE LOCATION–SPECIFIC ARARs AND TBCs
ALTERNATIVE GW–1 – NO ACTION
ALTERNATIVE GW–2 – LIMITED ACTION
OPTION GW–2A – LONG TERM MONITORING
OPTION GW–2B – DEED RESTRICTIONS
SITE 09 – ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Coastal Zones––				
	Coastal Zone Management Act (16 USC Section 1451 et seq.)	Applicable	Regulates activities affecting the coastal zone including lands thereunder and adjacent shoreline.	Since these alternatives do not involve activities which affect the coastal zone, they meet this ARAR.
STATE				
Wetlands––				
	Rhode Island Wetlands Laws (RIGL 2–1–18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh–water Wetlands Act – as amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Since these alternatives do not impact, a wetland area, they meet this ARAR.
Coastal Zone––				
	Rhode Island Coastal Resources Management Law, (RIGL, Title 46, Chapter 23) and Regulations	Applicable	Creates Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources.	Since these alternatives do not involve regulated activities as specified under the Coastal Resources Management Program, they meet this ARAR.

TABLE 4-16
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-2 - LIMITED ACTION
OPTION GW-2A - LONG TERM MONITORING
OPTION GW-2B - DEED RESTRICTIONS
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
FEDERAL				
Monitoring RCRA	RCRA 40 CFR 264.90-254.101 Subpart F - Ground Water Protection	Relevant and Appropriate	Ground water monitoring/corrective action requirements; dictates adherence to MCLs unless ACLS are appropriate and establishes points of compliance.	Monitoring standards will be met.
	RCRA Proposed Rule 52 FR 8712, 53 FR 51446 Proposed Amendments for Landfill Closures	To Be Considered	Provides an option for the application of alternate closure and post-closure requirements based on a consideration of site-specific conditions including exposure pathways of concern.	Long - term monitoring program will be designed taking into account exposure pathways of concern.
STATE				
Monitoring	RI Refuse Disposal Law Rules and Regulations for Solid Waste Management Facilities, Section 7.08	Relevant and Appropriate	Rules and regulations for well construction and development, and monitoring plan requirements at sanitary landfills.	Long-term monitoring program will comply with relevant and appropriate requirements.
	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.) Hazardous Waste Management Rules and Regulations			
	• Section 9	Relevant and Appropriate	Outlines operational requirements for treatment, storage and disposal facilities.	Ground water monitoring will comply with substantive portions of this section applicable to landfill closure.
	Rules and Regulations for Ground Water Quality	Applicable	Rules and regulations intended to protect and restore the quality of the State's ground water. Includes ground water program monitoring requirements and monitoring well construction and abandonment	Ground water monitoring programs and well construction/abandonment methodologies will comply with these regulations.

TABLE 4-17
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - CONTAINMENT
OPTION GW-3A - CAPPING
OPTION GW-3B - SHEET PILING
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Ground Water--				
	Resource Conservation and Recovery Act, Subpart F (40 CFR 264.94) Ground Water Protection Standards, Alternate Concentration Limits	Relevant and Appropriate	Allows for the development of alternate concentration limits (ACLs) for facilities which treat, store or dispose of hazardous waste when the characteristics of the ground water (e.g., high salinity) limit the application of Maximum Contaminant Levels or health-based criteria. Exposure-based ACLs may be developed which take into consideration potential adverse effects on ground water quality and hydraulically-connected surface water quality.	Ground water alternate concentration limits, although currently undeveloped, may be relevant and appropriate to the development of site-specific remediation levels.
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	To be Considered	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC, with modification, may be relevant and appropriate to the development of PRGs for ground water based on the potential discharge of ground water to surface water that is used for fishing.
STATE				
Ground Water --				
	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	To be determined	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	WQS, with modification, may be relevant and appropriate to the development of PRGs for ground water based on the potential discharge of ground water to surface water that is used for fishing.

TABLE 4-18
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - CONTAINMENT
OPTION GW-3A - CAPPING
OPTION GW-3B - SHEET PILING
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Wetlands/Water Resources--				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Will be applicable if cap construction or sheet piling installation impact coastal or on-shore wetland areas.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredge or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Filling a Navigable Water	Applicable	Prohibits the discharge of dredged or fill material to a water of the United States if there is a practicable alternative which poses less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	Applicable if cap construction or sheet piling installation impact wetlands and waters, or cause degradation of water. If construction cannot be limited to when toeprint of existing landfill, mitigation of impacted wetlands may be required.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making process which may impact water bodies, including wetlands. Measures to prevent, mitigate or compensate for losses of fish and wildlife will be given due consideration whenever a modification of a water body is proposed.	ARAR for cap construction and for sheet piling installation, if they impact Allen Harbor

TABLE 4-18 (Continued)
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - CONTAINMENT
OPTION GW-3A - CAPPING
OPTION GW-3B - SHEET PILING
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Coastal Zones--				
	Coastal Zone Management Act (16 USC Section 1451 et seq.)	Applicable	Regulates activities affecting the coastal zone including lands thereunder and adjacent shoreline.	ARAR for cap construction and sheet piling installation.
STATE				
Wetlands--				
	Rhode Island Wetlands Laws (RIGL 2-1-18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh-water Wetlands Act - as amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Regulation will be applicable if cap construction or sheet piling installation impact a freshwater wetland area.
Coastal Zone--				
	Rhode Island Coastal Resources Management Law, (RIGL, Title 46, Chapter 23) and Regulations	Applicable	Creates Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources.	Since Allen Harbor Landfill is located in a coastal area, the Navy will coordinate with the Rhode Island Coastal Resources Management Council and will ensure that all actions are consistent, to the maximum extent practicable, with the Coastal Zone Management Plan. ARAR for capping and sheet piling installation.

TABLE 4-19
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - CONTAINMENT
OPTION GW-3A - CAPPING
OPTION GW-3B - SHEET PILING
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
FEDERAL				
Drainage/ Discharge	Clean Water Act (40 CFR 122-125) National Pollutant Discharge Elimination System (NPDES) Permit Requirements	Applicable	Permits contain applicable effluent standards (i.e. technology- and/or water quality-based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste from industrial facilities.	Any storm water drainage improvements would be designed to provide compliance with these regulations and drainage/discharge would be monitored in compliance with these regulations.
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	Relevant and Appropriate	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC will be relevant and appropriate to the development of discharge criteria for storm water, as described above.
Capping/ Monitoring	Migratory Bird Treaty Act (16 U.S.C. 703-712)	Applicable	Prohibits hunting, possessing, killing, or capturing of migratory birds, birds in danger of extinction, and those birds' eggs or nests.	Since construction activities during the breeding season may "take" birds or their nests, actions must be taken to avoid destroying nests during breeding season.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredged or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Wetland Filling	Applicable	Prohibits the discharge of dredged or fill material to waters of the United States unless no other practical alternatives are available which pose less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	If cap construction or sheet piling installation cannot be limited to areas within the toeprint of the existing landfill, mitigation of any impacted wetlands will be required.

TABLE 4–19(Continued)
FEDERAL AND STATE ACTION–SPECIFIC ARARs AND TBCs
ALTERNATIVE GW–3 – CONTAINMENT
OPTION GW–3A – CAPPING
OPTION GW–3B – SHEET PILING
SITE 09 – ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Capping/ Monitoring (cont.)	RCRA (40 CFR 264) Subtitle C Requirements:	Relevant and Appropriate	Outlines specifications and standards for design, operation, closure and monitoring of performance for hazardous waste storage, treatment and disposal facilities.	Substantive RCRA requirements will be met and adhered to on–site if appropriate, based on the specific remedial action.
	40 CFR 264.110–118 Subpart G – Closure/Post Closure Requirements	Relevant and Appropriate	Establishes requirements for the closure and long–term management of a hazardous disposal facility.	Relevant and appropriate standards and requirements will be met.
	40 CFR 264.301–264.310; Subpart N – Landfill Requirements	Relevant and Appropriate	Placement of cap over hazardous waste requres a cover designed and constructed to comply with regulations. Installation of final cover to provide long–term minimization of infiltration. Restricts post–closure use of property as necessary to prevent damage to cover.	Cap designs will meet relevant and appropriate requirements.
	RCRA Proposed Rule 52 FR 8712, 53 FR 51446 Proposed Amendments for Landfill Closures	To Be Considered	Provides an option for the application of alternate closure and post–closure requirements based on a consideration of site–specific conditions including exposure pathways of concern.	Cap and post–closure monitoring designs take into account exposure pathways of concern.
	EPA Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments (EPA 530–SW–89–047)	To Be Considered	EPA Technical Guidance for landfill covers. Presents recommended technical specifications for multilayer landfill cover design.	Standards will be considered in development of the cap design.

TABLE 4-19(Continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - CONTAINMENT
OPTION GW-3A - CAPPING
OPTION GW-3B - SHEET PILING
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air	Clean Air Act (40 CFR 60) New Source Performance Standards (NSPS) Proposed Subpart WWW 56 FR 24468-24528 (5/30/91)	To Be Considered	Requires Best Demonstrated Technology (BDT) for new sources, and sets emissions limitations. Proposed Subpart WWW sets a performance standard for non-methane organic compounds (NMOC) emissions of 150 Mg/yr (167 tpy) for existing municipal solid waste landfills.	These standards should be considered if a landfill gas management system is required.
	Clean Air Act (40 CFR 61) National Emissions Standards for Hazardous Pollutants (NESHAP)	To Be Considered	Establishes emissions limitations for hazardous air pollutants and sets forth regulated sources of those pollutants.	Although EPA has not promulgated final Maximum Achievable Control Technology (MACT) standards for municipal landfills, the lead agency should use air control technology to control emissions of hazardous air pollutions. MACT standards prescribe technology that is used by the best 12% of industries in the source category.
	Clean Air Act, Section 5 171 through 178, 42 USC §§ 7471-7478 (Requirements for Non-Attainment Areas)	Applicable or Relevant and Appropriate (Depending on Modelling Results)	RI has adopted State Implementation Plan (SIP) requirements approved and enforcable by EPA which meet the New Source Review (NSR) requirement of the CAA. These provisions require that new or modified major sources of VOCs defined as a source which has the potential to emit 50 tpy install equipment to meet Lowest Available Emissions Rate (LAER), which is set on a case-by-case basis and is either the most stringent emissions limitation contained in any SIP for that category or source or the most stringent emissions limitation which is achieved for the source. NSR requirements apply to non-attainment pollutants, which are VOCs and NO_x in RI.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels and on the need to be protective of human health and the environment.

TABLE 4-19(Continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - CONTAINMENT
OPTION GW-3A - CAPPING
OPTION GW-3B - SHEET PILING
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	Clean Air Act, Section 5 160 through 169A - Prevention of Significant Deterioration Provisions	Applicable or Relevant and Appropriate (Depending on Modelling Results)	RI has adopted SIP requirements approved and enforceable by EPA which meet the Prevention of Significant Deterioration (PSD) requirements of the CAA. These provisions require that new or modified major sources of VOCs, defined as a source which has the potential to emit 25 tons/year, install equipment to meet Best Available Control Technology (BACT). PSD requirements apply to attainment pollutants, which are SO2, CO, lead and particulates in Rhode Island.	Monitoring will be conducted as appropriate to determine if the requirements of this standard are applicable or relevant and appropriate based on the emmissions levels.
STATE Drainage/ Discharge	RI Water Pollution Control Act			
	• RI Water Quality Regulations for Water Pollution Control (RIGL 46-12, et seq.) RI Water Quality Standards	Applicable	Establishes general requirements and effluent limits for discharge to area waters.	In compliance with these regulations, RIPDES requirements pertaining to storm water discharges or treatment system discharges would be met.
	• Regulations for the RI Pollutant Discharge Elimination System (RIPDES) (RIGL 46-12, et seq.)	Applicable	Permits contain applicable effluent (i.e. technology - based and/or water quality - based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste.	Storm water discharge improvements would be designed to provide compliance with these regulations and drainage/discharge would be monitored in compliance with these regulations.
Capping/ Monitoring	RI Refuse Disposal Law Rules and Regulations for Solid Waste Management Facilities	Relevant and Appropriate	Rules and regulations intended to minimize environmental hazards associated with the operation of solid waste transfer, resource recovery, and disposal facilities.	Closure design criteria and ground water monitoring requirements may be relevant and apppropriate if a RCRA hybrid cap is considered.

TABLE 4-19(Continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - CONTAINMENT
OPTION GW-3A - CAPPING
OPTION GW-3B - SHEET PILING
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Capping/ Monitoring (cont.)	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq Hazardous Waste Management Rules and Regulations	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage and disposal.	Substantive requirements applicable to closure will be met and adhered to on-site.
	• Section 7	Relevant and Appropriate	Restricts location, design, construction, and operation of landfills from endangering ground water, wetlands or floodplains.	Remedial actions will be designed so as to prevent contamination of ground water, wetlands, or floodplains.
	• Section 8	Relevant and Appropriate	Outlines requirements for ground water protection, general waste analysis, security procedures, inspections and safety.	Remedial actions will comply with substantive portions of this section applicable to landfill closure.
	• Section 9	Relevant and Appropriate	Outlines operational requirements for treatment, storage and disposal facilities.	Remedial actions, including ground water monitoring, will comply with substantive portions of this section applicable to landfill closure.
	• Section 10	Relevant and Appropriate	Outlines design and operations requirements for land disposal facilities, including landfills.	Remedial actions will meet all non-location specific requirements of this section applicable to landfill closure.

TABLE 4-19(Continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - CONTAINMENT
OPTION GW-3A - CAPPING
OPTION GW-3B - SHEET PILING
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air	RI Clean Air Act (RIGL, Title 23, Chapter 23) General Air Quality and Air Emissions Requirements			
	• RI Air Pollution Control Regulations, RI Dept. of Health, Div. of Air Pollution Control, effective 8/2/67, most recently amended 5/20/91			
	– Regulation No. 1 – Visible Emissions	Applicable	No air contaminant emissions will be allowed for more than 3 minutes in any one hour which are greater than or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulation.
	– Regulation No. 5 – Fugitive Dust	Applicable	Requires that reasonable precaution be taken to prevent particulate matter from becoming airborne.	On-site remedial actions will use good industrial practices to prevent particulate matter from becoming airborne.
	– Regulation No. 7 – Emissions Detrimental to Person or Property	Applicable	Prohibits emissions of contaminants which may be injurious to human, plant or animal life or cause damage to property or which reasonably interferes with the enjoyment of life and property.	All emissions will meet this requirement or gas treatment will be required.
	– Regulation No. 9 – Approval to Construct, Install, Modify or Operate	Applicable	Establishes guidelines for the construction, installation, modification or operation of potential air emission units. Establishes permissible emission rates for some contaminants.	Technologies involving construction, installation, modification or operation of air emission units will meet these requirements.
	– Regulation No. 15 – Control of Organic Solvent Emissions	Applicable	Limits the amount of organic solvents emitted to the atmosphere.	If emissions exceed limits in this regulation, emission controls will be designed and implemented to meet these requirements.

TABLE 4–19(Continued)
FEDERAL AND STATE ACTION–SPECIFIC ARARs AND TBCs
ALTERNATIVE GW–3 – CONTAINMENT
OPTION GW–3A – CAPPING
OPTION GW–3B – SHEET PILING
SITE 09 – ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	– Regulation No. 17 – Odors	Applicable	Prohibits the release of objectionable odors across property lines.	No remedial action or air emissions will emit objectionable odors beyond the facility boundary, as practicable.
	– Regulation No. 22 – Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels or acceptable ambient levels with LAER, as set in the regulation.	If air emissions contain regulated substances, air emissions control equipment will be used as necessary to meet these standards.

TABLE 4-20
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-4 - EXTRACTION/TREATMENT/DISCHARGE
OPTIONS GW-4A THROUGH GW-4F
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Ground Water--				
	Resource Conservation and Recovery Act, Subpart F (40 CFR 264.94) Ground Water Protection Standards, Alternate Concentration Limits	Relevant and Appropriate	Allows for the development of alternate concentration limits (ACLs) for facilities which treat, store or dispose of hazardous waste when the characteristics of the ground water (e.g., high salinity) limit the application of Maximum Contaminant Levels or health-based criteria. Exposure-based ACLs may be developed which take into consideration potential adverse effects on ground water quality and hydraulically-connected surface water quality.	Ground water alternate concentration limits, although currently undeveloped, may be relevant and appropriate to the development of site-specific remediation levels.
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	To be Considered	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC, with modification, may be relevant and appropriate to the development of PRGs for ground water based on the potential discharge of ground water to surface water that is used for fishing.
Surface Water --				
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	Relevant and Appropriate or Applicable	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC are relevant and appropriate to the development of PRGs for surface water. AWQC will also be applicable to remedial alternatives which involve discharges to surface water.

TABLE 4-20(Continued)
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-4 - EXTRACTION/TREATMENT/DISCHARGE
OPTIONS GW-4A THROUGH GW-4F
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Soils/Surfaces--				
	Toxicity Characteristic (40 CFR 261.24)	To be determined	Establishes maximum concentrations of contaminants for the toxicity characteristic using the test method described in 40 CFR 261 Appendix II.	Applicable where wastes produced as a byproduct of a remedial action require handling as a hazardous waste on the basis of the Toxic Characteristic Leachate Parameter (TCLP) analysis.
	Land Disposal Restrictions (40 CFR 268)	To be determined	Establishes maximum concentrations of contaminants on the basis of which hazardous wastes are restricted from land disposal.	This regulation will be applicable to remedial alternatives which utilize land disposal of hazardous waste.
Air--				
	Clean Air Act (40 CFR 50) National Ambient Air Quality Standards (NAAQS)	To be determined	Establishes maximum levels for pollutants and particulates within air quality control districts.	Potential ARARS for alternatives involving remedial actions which impact ambient air (i.e. incinerators, soil venting, etc.).
	Clean Air Act (40 CFR 60) New Source Performance Standards (NSPS)	To be determined	Establishes emissions limitations for new sources.	Potential ARARS for alternatives involving treatment methods which emit pollutants.
	Clean Air Act (40 CFR 61) National Emissions Standard for Hazardous Air Pollutants	To be determined	Establishes emissions standards for hazardous air pollutants.	Potential ARARS for alternatives involving treatment methods which emit hazardous air pollutants.

TABLE 4-20(Continued)
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-4 - EXTRACTION/TREATMENT/DISCHARGE
OPTIONS GW-4A THROUGH GW-4F
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
STATE				
Ground Water --				
	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	To be determined	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	WQS, with modification, may be relevant and appropriate to the development of PRGs for ground water based on the potential discharge of ground water to surface water that is used for fishing.
Surface Water --				
	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	Relevant and Appropriate or Applicable	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	WQS are relevant and appropriate to the development of PRGs for surface water. WQS will also be applicable for remedial alternatives which involve discharges to surface water.
Soils/Surfaces--				
	RI Hazardous Waste Management Act of 1987 (RIGL 23-19.1 et seq.) Rules and Regulations for Hazardous Waste Management	Applicable	Defines Type 6 - Extremely hazardous waste as including wastes which contain PCBs at a concentration of 50 ppm or greater or showing 10 $\mu g/100\ cm^2$ or greater as measured by a standard wipe test.	Will be applicable for remedial alternatives which involve handling of materials which meet the definition of a hazardous waste.
	Rules and Regulations for Solid Waste Management Facilities	Applicable	Defines solid waste as including any soil, debris or other material with a concentration of PCBs of 10 ppm or greater or containing 2 $\mu g/100\ cm^2$ or greater as measured by a standard wipe test.	Will be applicable for remedial alternatives which involve handling of materials which meet the definition of a solid waste.
Air--				
	RI Clean Air Act (RIGL Title 23, Chapter 23) Air Pollution Control Regulation Standards	To be determined	Establishes maximum ambient levels for criteria pollutants.	Potential ARARs for remedial alternatives involving treatment methods which emit criteria pollutants.

TABLE 4–21
FEDERAL AND STATE LOCATION–SPECIFIC ARARs AND TBCs
ALTERNATIVE GW–4
OPTIONS GW–4A THROUGH GW–4F
SITE 09 – ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Wetlands/Water Resources––				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long– and short–term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Since these alternatives do not impact coastal or on–shore wetland areas, they meet this ARAR.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredge or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Filling a Navigable Water	Applicable	Prohibits the discharge of dredged or fill material to a water of the United States if there is a practicable alternative which poses less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	Since these alternatives do not involve the discharge of dredged or fill material, they meet this ARAR.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision–making process which may impact water bodies, including wetlands. Measures to prevent, mitigate or compensate for losses of fish and wildlife will be given due consideration whenever a modification of a water body is proposed.	Since these alternatives do not involve modification of a water body, they meet this ARAR.

TABLE 4-21 (Continued)
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-4
OPTIONS GW-4A THROUGH GW-4F
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Coastal Zones--	Coastal Zone Management Act (16 USC Section 1451 et seq.)	Applicable	Regulates activities affecting the coastal zone including lands thereunder and adjacent shoreline.	For remedial actions in a coastal zone, requires determination that all activities are consistent to the maximum extent practicable with State Coastal Zone Management Plan.
STATE				
Wetlands--	Rhode Island Wetlands Laws (RIGL 2-1-18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh-water Wetlands Act - as amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Since these alternatives do not impact a wetland area, they meet this ARAR.
Coastal Zone--	Rhode Island Coastal Resources Management Law, (RIGL, Title 46, Chapter 23) and Regulations	Applicable	Creates Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources.	Since Allen Harbor Landfill is located in a coastal area, the Navy will coordinate with the Rhode Island Coastal Resources Management Council and will ensure that all actions are consistent, to the maximum extent practicable, with the Coastal Zone Management Plan.

TABLE 4-22
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-4
OPTIONS GW-4A THROUGH GW-4F
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
FEDERAL				
Drainage/ Discharge	Clean Water Act (40 CFR 122-125) National Pollutant Discharge Elimination System (NPDES) Permit Requirements	Applicable	Permits contain applicable effluent standards (i.e. technology- and/or water quality-based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste from industrial facilities.	Treatment system discharges would be monitored in compliance with these regulations.
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	Relevant and Appropriate	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC will be applicable to remedial alternatives which involve discharges to surface water.
Construction	Migratory Bird Treaty Act (16 U.S.C. 703-712)	Applicable	Prohibits hunting, possessing, killing, or capturing of migratory birds, birds in danger of extinction, and those birds' eggs or nests.	Since construction activities during the breeding season may "take" birds or their nests, actions must be taken to avoid destroying nests during breeding season.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredged or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Wetland Filling	Applicable	Prohibits the discharge of dredged or fill material to waters of the United States unless no other practical alternatives are available which pose less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	If it is determined that a remedial action cannot be limited to areas within the toeprint of the existing landfill, mitigation of any impacted wetlands will be required.

TABLE 4–22(Continued)
FEDERAL AND STATE ACTION–SPECIFIC ARARs AND TBCs
ALTERNATIVE GW–4
OPTIONS GW–4A THROUGH GW–4F
SITE 09 – ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
<u>Venting/ Discharges to Air</u>	Clean Air Act, Section 5 171 through 178, 42 USC §§ 7471–7478 (Requirements for Non–Attainment Areas)	Applicable or Relevant and Appropriate (Depending on Modelling Results)	RI has adopted State Implementation Plan (SIP) requirements approved and enforcable by EPA which meet the New Source Review (NSR) requirement of the CAA. These provisions require that new or modified major sources of VOCs defined as a source which has the potential to emit 50 tpy install equipment to meet Lowest Available Emissions Rate (LAER), which is set on a case–by–case basis and is either the most stringent emissions limitation contained in any SIP for that category or source or the most stringent emissions limitation which is achieved for the source. NSR requirements apply to non–attainment pollutants, which are VOCs and NO_x in RI.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels and on the need to be protective of human health and the environment.
	Clean Air Act, Section 5 160 through 169A – Prevention of Significant Deterioration Provisions	Applicable or Relevant and Appropriate (Depending on Modelling Results)	RI has adopted SIP requirements approved and enforceable by EPA which meet the Prevention of Significant Deterioration (PSD) requirements of the CAA. These provisions require that new or modified major sources of VOCs, defined as a source which has the potential to emit 25 tons/year, install equipment to meet Best Available Control Technology (BACT). PSD requirements apply to attainment pollutants, which are SO2, CO, lead and particulates in Rhode Island.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels.

TABLE 4–22(Continued)
FEDERAL AND STATE ACTION–SPECIFIC ARARs AND TBCs
ALTERNATIVE GW–4
OPTIONS GW–4A THROUGH GW–4F
SITE 09 – ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	RCRA 40 CFR 265.375 Subpart P – Thermal Treatment	Applicable	Establishes requirements for air emissions from thermal treatment units.	Remedial actions which involve thermal treatment units, as defined in 40 CFR 265.370, will meet these standards.
	RCRA 40 CFR 264.1030 – 264.1036 Subpart AA – Air Emission Standards for Process Vents	Applicable	Establishes standards for air emissions from process vents associated with distillation, fractionation, thin film evaporation, column extraction or air steam stripping operations that treat RCRA substances and have total organic concentrations of 10 ppm or greater.	If these technologies are utilized and the threshold organic concentration is met, air emissions will comply with the standards.
	RCRA 40 CFR 264.1050 – 264.1065 Subpart BB – Air Emission Standards for Equipment Leaks	Applicable	Establishes standards for air emissions for equipment that contains or contacts RCRA wastes with organic concentrations of at least 10% by weight.	If such concentrated wastes are treated, the equipment used will meet these standards.
	EPA Technical Guidance Document: Control of Air Emissions from Superfund Air Strippers at Superfund Ground Water Sites (OSWER Directive 9355.0.28)	To Be Considered	Guidance regarding the control of air emissions from air strippers used at Superfund sites for ground water treatment. Distinguishes between attainment and non–attainment areas for ozone.	These guidelines will be considered if air stripping is used as a ground water treatment alternative.
	RCRA 40 CFR 264 Proposed Subpart CC Organics Air Emission Standards for Tanks, Surface Impoundments, and Containers (56 FR 33490, 7/22/91)	To Be Considered	Proposed standards for air emissions from tanks, surface impoundments, and containers with VOC concentrations equal to or greater than 500 ppm.	Proposed standards will be considerd for remedial alternatives which involve the storage or treatment of hazardous wastes in tanks, surface impoundments, or containers if threshold VOC concentrations are met.

TABLE 4-22(Continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-4
OPTIONS GW-4A THROUGH GW-4F
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
<u>Treatment</u>	RCRA 40 CFR 261 Identification and Listing of Hazardous Wastes	Applicable	Defines those solid wastes which are subject to regulation as hazardous wastes under 40 CFR Parts 262-265.	Wastes generated during implementation of remedial actions will be evaluated to determine if they are listed or characteristic hazardous waste.
	RCRA (40 CFR 264) Subtitle C Requirements:	Relevant and Appropriate	Outlines specifications and standards for design, operation, closure and monitoring of performance for hazardous waste storage, treatment and disposal facilities.	Substantive RCRA requirements will be met and adhered to on-site if appropriate, based on the specific remedial action.
	• 40 CFR 264.10-264.18 Subpart B - General Facility Standards	Relevant and Appropriate	General requirements regarding waste analysis, security, training, inspections, and location applicable to a facility which stores, treats or disposes of hazardous wastes (a TSDF facility).	This regulation may be applicable to remedial actions which address a waste which is a listed or characteristic waste under RCRA and which constitute current treatment, storage, or disposal as certified by RCRA.
	• 40 CFR 264.30-264.37 Subpart C - Preparedness and Prevention	Relevant and Appropriate	Requirements applicable to the design and operation, equipment, and communications associated with a TSDF facility, and to arrangements with local response departments.	This regulation may be applicable to remedial actions which address a waste which is a listed or characteristic waste under RCRA and which constitute current treatment, storage, or disposal as certified by RCRA.
	• 40 CFR 264.50-264.56 Subpart D - Contingency Plan and Emergency Procedures	Relevant and Appropriate	Emergency planning procedures applicable to a TSDF facility.	This regulation may be applicable to remedial actions which address a waste which is a listed or characteristic waste under RCRA and which constitute current treatment, storage, or disposal as certified by RCRA.
	• RCRA 40 CFR 265.400 - 265.406 Subpart Q - Chemical, Physical, and Biological Treatment	Applicable	General operating, waste analysis and trial test, inspection and closure requirements for facilities which treat hazardous waste by chemical, physical or biological methods in other than tanks, surface impoundments and land treatment facilities.	Remedial alternatives which utilize chemical, physical and biological treatment methods as described to treat hazardous wastes will meet these requirements.

TABLE 4-22(Continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-4
OPTIONS GW-4A THROUGH GW-4F
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Treatment (cont.)	• RCRA 40 CFR 264.600 - 264.603 Subpart X - Miscellaneous Units	Applicable	Defines performance standards, monitoring and post-closure requirements for miscellaneous units, as defined in 40 CFR 264.10.	Remedial alternatives which utilize miscellaneous units to treat hazardous wastes will meet these requirements.
STATE				
Drainage/ Discharge	RI Water Pollution Control Act			
	• RI Water Quality Regulations for Water Pollution Control (RIGL 46-12, et seq.) RI Water Quality Standards	Applicable	Establishes general requirements and effluent limits for discharge to area waters.	In compliance with these regulations, RIPDES requirements pertaining to treatment system discharges would be met.
	• Regulations for the RI Pollutant Discharge Elimination System (RIPDES) (RIGL 46-12, et seq.)	Applicable	Permits contain applicable effluent (i.e. technology - based and/or water quality - based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste.	Ground water treatment systems would be designed to provide compliance with these regulations and discharge would be monitored in compliance with these regulations.
Monitoring				
	Rules and Regulations for Ground Water Quality	Applicable	Rules and regulations intended to protect and restore the quality of the State's ground water. Includes ground water program monitoring requirements and monitoring well construction and abandonment standards.	Ground water monitoring programs and well construction/abandonment methodologies will comply with these regulations.

TABLE 4–22(Continued)
FEDERAL AND STATE ACTION–SPECIFIC ARARs AND TBCs
ALTERNATIVE GW–4
OPTIONS GW–4A THROUGH GW–4F
SITE 09 – ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air	RI Clean Air Act (RIGL, Title 23, Chapter 23) General Air Quality and Air Emissions Requirements • RI Air Pollution Control Regulations, RI Dept. of Health, Div. of Air Pollution Control, effective 8/2/67, most recently amended 5/20/91			
	– Regulation No. 1 – Visible Emissions	Applicable	No air contaminant emissions will be allowed for more than 3 minutes in any one hour which are greater than or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulation.
	– Regulation No. 5 – Fugitive Dust	Applicable	Requires that reasonable precaution be taken to prevent particulate matter from becoming airborne.	On–site remedial actions will use good industrial practices to prevent particulate matter from becoming airborne.
	– Regulation No. 7 – Emissions Detrimental to Person or Property	Applicable	Prohibits emissions of contaminants which may be injurious to human, plant or animal life or cause damage to property or which reasonably interferes with the enjoyment of life and property.	All emissions will meet this requirement or gas treatment will be required.
	– Regulation No. 9 – Approval to Construct, Install, Modify or Operate	Applicable	Establishes guidelines for the construction, installation, modification or operation of potential air emission units. Establishes permissible emission rates for some contaminants.	Technologies involving construction, installation, modification or operation of air emission units will meet these requirements.
	– Regulation No. 15 – Control of Organic Solvent Emissions	Applicable	Limits the amount of organic solvents emitted to the atmosphere.	If emissions exceed limits in this regulation, emission controls will be designed and implemented to meet these requirements.

TABLE 4-22(Continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-4
OPTIONS GW-4A THROUGH GW-4F
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	- Regulation No. 17 - Odors	Applicable	Prohibits the release of objectionable odors across property lines.	No remedial action or air emissions will emit objectionable odors beyond the facility boundary, as practicable.
	- Regulation No. 22 - Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels or acceptable ambient levels with LAER, as set in the regulation.	If air emissions contain regulated substances, air emissions control equipment will be used as necessary to meet these standards.
Treatment	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.) Hazardous Waste Management Rules and Regulations	Applicable	Rules and regulations for hazardous waste generation, transportation, treatment, storage and disposal.	Substantive requirements applicable to hazardous waste treatment will be met and adhered to on-site.
	• Section 8	Applicable	Outlines operational requirements for all hazardous waste treatment facilities.	Any hazardous waste treatment actions will comply with the substantive requirements of this section which apply to treatment technologies.
	• Section 9	Applicable	Outlines requirements for general waste analysis, security procedures, inspections and safety.	All remedial actions involving treatment of hazardous wastes will comply with the applicable portions of this section.
	• Section 13	Applicable	Outlines design and operational requirements for miscellaneous units, as defined in 40 CFR 260.10.	Remedial alternatives which utilize miscellaneous units to treat hazardous wastes will meet the applicable requirements of this section.

TABLE 4-23
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternativ GW-1 - No Action	Least protective alternative; Does not limit future use of the site and does not monitor for potential future environmental impacts due to ground water/leachate migration; Does not provide any containment of leachate seeps; Does not present any short-term impacts; Does not meet remedial response objectives
Alternative GW-2 - Limited Action	Provides protection through long-term monitoring and through the elimination of potential exposure through the institution of deed restrictions; Does not limit potential exposures or impacts associated with leachate seeps
Option GW-2A - Long-Term Monitoring	Provides a means of monitoring changes in ground water, sediment and surface water quality which may be attributable to ground water migration and discharge; Does not address potential exposures to or impacts associated with leachate seeps or potential future well installation on-site
Option GW-2B - Deed Restrictions	Provides a means of limiting potential exposures to ground water which could occur if a well were installed on-site in the future; Does not address potential ground water migration or leachate seeps
Alternative GW-3 - Containment	Provides protection of human health and the environment by limiting potential ground water migration; Would comply with location-specific and action-specific ARARs; Some increased short-term risks would result during implementation; Would be effective in the long-term
Option GW-3A - Capping	Provides a physical barrier to leachate seeps and infiltration of precipitation; Does not address potential ground water migration; Would comply with location-specific and action-specific ARARs; Some increased short-term risks would result during implementation; Would be effective in the long-term
Option GW-3B - Sheet Piling	Provides a physical barrier to ground water migration in and out of the landfill area; Would also provide a physical barrier to leachate seeps along shoreline of Allen Harbor; Would comply with location-specific and action-specific ARARs; Some increased short-term risks would result during implementation; Would be effective in the long-term (40-year design life)

TABLE 4-23 (continued)
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative GW-4 - Extraction/Treatment/Discharge	While this alternative provides active treatment of ground water, and thereby minimizes the potential migration of contaminated ground water and subsequent environmental impacts, the long-term effectiveness of this alternative is not well-defined; Upon discontinuation of treatment, ground water could resaturate subsurface waste materials and become re-contaminated; Would comply with action-specific and location-specific ARARs; Would be effective in the short-term
Option GW-4A - Extraction	Effective in terms of overall protection of human health and the environment; would comply with ARARs; Effective and reliable in the long-term and in the short-term
Option GW-4B - Air Stripping	Effective in terms of overall protection of human health and the environment; would comply with ARARs; Effective and reliable in the long-term and in the short-term
Option GW-4C - UV Oxidation	Effective in terms of overall protection of human health and the environment; would comply with ARARs; Effective and reliable in the long-term and in the short-term
Option GW-4D - Precipitation	Effective in terms of overall protection of human health and the environment; would comply with ARARs; Effective and reliable in the long-term and in the short-term
Option GW-4E - Membrane Microfiltration	Effective in terms of overall protection of human health and the environment; expected to comply with ARARs although treatability studies would be required; Effective and reliable in the long-term and in the short-term
Option GW-4F - Discharge to Surface Water	Effective in terms of overall protection of human health and the environment; would comply with ARARs; Effective and reliable in the long-term and in the short-term

TABLE 4-24
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVES
COMPLIANCE WITH ARARS
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	CHEMICAL-SPECIFIC	LOCATION-SPECIFIC	ACTION-SPECIFIC
Alternative GW-1 - No Action	Ambient Water Quality Criteria (AWQC) exceeded in ground water but due to lack of ecological impacts definitely attributable to ground water discharge, modification of AWQC may be appropriate before application as ground water ARARs	Meets criteria; Involves no actions which impact coastal or wetland areas	Not applicable
Alternativ GW-2 - Limited Action	See GW-1	Meets criteria; Involves no actions which impact coastal or wetland areas	Monitoring would comply with landfill closure monitoring requirements
Option GW-2A - Long-Term Monitoring	See GW-1	Meets criteria; Involves no actions which impact coastal or wetland areas	Monitoring would comply with landfill closure monitoring requirem nts
Option GW-2B - Deed Restrictions	See GW-1	Meets criteria; Involves no actions which impact coastal or wetland areas	Not applicable
Alternative GW-3 - Containment	See GW-1	Implementation of construction activities would comply with criteria (i.e. wetland and coastal requirements); Mitigation of any impacted wetlands may be required	Would meet action-specific ARARs, as described for each option below
Option GW-3A - Capping	See GW-1	See GW-3	Would comply with criteria applicabl to storm water discharg , venting, and relevant and appropriat landfill closure requirements
Option GW-3B - Sheet Piling	See GW-1	See GW-3	Would comply with criteria applicable to on-site construction activities

TABLE 4-24 (continued)
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVES
COMPLIANCE WITH ARARS
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	CHEMICAL-SPECIFIC	LOCATION-SPECIFIC	ACTION-SPECIFIC
Alternative GW-4 - Extraction/Treatment/ Discharge	See GW-1; Extraction/treatment/ discharge alternative developed to treat contaminants detected at levels exceeding AWQC	Implementation of construction and operational activities would comply with criteria (i.e. wetland and coastal zone requirements); Mitigation of any impacted wetlands may be required	Would meet action-specific ARARs, as described for each option below
Option GW-4A - Extraction	See GW-4	Installation of extraction wells would comply with criteria (i.e. wetland and coastal zone requirements)	Would meet action-specific ARARs applicable to ground water extraction, including well construction standards
Option GW-4B - Air Stripping	See GW-4; Would meet chemical-specific water discharge and air emission requirements	Treatment system construction would comply with criteria (i.e. wetland and coastal zone requirements)	Would comply with air discharge, hazardous waste characterization, and effluent discharge requirements
Option GW-4C - UV Oxidation	See GW-4; Would meet chemical-specific water discharge requirements	Treatment system construction would comply with criteria (i.e. wetland and coastal zone requirements)	Would comply with hazardous waste characterization and effluent discharge requirements
Option GW-4D - Precipitation	See GW-4; Would meet chemical-specific water discharge requirements	Treatment system construction would comply with criteria (i.e. wetland and coastal zone requirements)	Would comply with hazardous waste characterization and effluent discharge requirements
Option GW-4E - Membrane Microfiltration	See GW-4; Expected to meet chemical-specific water discharge requirements	Treatment system construction would comply with criteria (i.e. wetland and coastal zone requirements)	Would comply with hazardous waste characterization and effluent discharge requirements
Option GW-4F - Discharge to Surface Water	See GW-4; Would meet chemical-specific water discharge requirements	Discharge system construction would comply with criteria (i.e. wetland and coastal zone requirements)	Would comply with effluent discharge requirements

TABLE 4-25
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative GW-1 - No Action	Provides no long-term protection against ground water migration and no means of monitoring potential associated environmental impacts; Requires 5-year review
Alternative GW-2 - Limited Action	Utilizes institutional controls to monitor potential increases in ecological risks and to minimize potential human human exposures to contaminated ground water; Is not effective in addressing leachate seeps; Requires 5-year review
Option GW-2A - Long-Term Monitoring	Long-term monitoring of ground water, surface water and sediment quality provides a means of identifying ecological impacts due to degradation
Option GW-2B - Deed Restrictions	Deed restrictions must be maintained to prohibit potential construction of an on-site well
Alternative GW-3 - Containment	Effective in the long-term minimization of leachate seeps and/or contaminated ground water migration; Requires 5-year review
Option GW-3A - Capping	Effective in the long-term minimization of leachate seeps from the landfill surface; Minor maintenance required
Option GW-3B - Sheet Piling	Effective in the long-term minimization of ground water flow into and out of the landfill area; Requires long-term maintenance

TABLE 4-25 (continued)
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative GW-4 - Extraction/Treatment Discharge	Effective in dewatering and treating upper aquifer if combined with containment alternatives; Permanence is not ensured when treatment is discontinued; Ground water may re-saturate waste materials and become re-contaminated.
Option GW-4A - Extraction	Extraction wells offer good effectiveness in the long-term extraction of contaminated ground water, requiring periodic maintenance
Option GW-4B - Air Stripping	Good long-term effectiveness in removing volatile organic contaminants; Easily operated and maintained; May require off-gas treatment
Option GW-4C - UV Oxidation	Good long-term effectiveness anticipated; More labor-intensive in terms of operation and maintenance requirements than Alternative GW-4B; Produces harmless treatment residuals
Option GW-4D - Precipitation	Effective in the long-term; Requires long-term sludge handling
Option GW-4E - Membrane Microfiltration	Treatability studies required to demonstrate effectiveness; Requires long-term sludge handling
Option GW-4F - Discharge to Surface Water	Effective in the long-term with minimal maintenance required

TABLE 4-26
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVE
REDUCTION OF TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative GW-1 - No Action	Provides no reduction in toxicity, mobility or volume through treatment
Alternative GW-2 - Limited Action (including GW-2A and GW-2B)	Provides no reduction in toxicity, mobility or volume through treatment
Alternative GW-3 - Containment	Provides no reduction in toxicity, mobility or volume through treatment; Reduces ground water mobility through containment features
Option GW-3A - Capping	Reduces ground water mobility by removing migration pathway for leachate seeps
Option GW-3B - Sheet Piling	Reduces ground water mobility by minimizing ground water flow into and out of landfill area
Alternative GW-4 - Extraction/Treatment Discharge	Reduces ground water toxicity through treatment
Option GW-4A - Extraction	Extraction reduces ground water mobility but provides no treatment in and of itself
Option GW-4B - Air Stripping	Reduces toxicity of volatile organic containments through removal and potential off-gas treatment, if necessary
Option GW-4C - UV Oxidation	Reduces toxicity of organic contaminants by breaking down contaminants into harmless by-products
Option GW-4D - Precipitation	Reduces toxicity of dissolved and undissolved inorganic contaminants through removal, consolidation and disposal
Option GW-4E - Membrane Microfiltration	Reduces toxicity of suspended inorganic contaminants through physical removal, consolidation and disposal.
Option GW-4F - Discharge to Surface Water	Provides no reduction in toxicity, mobility or volume through treatment

TABLE 4-27
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVE
SHORT-TERM EFFECTIVENESS
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative GW-1 - No Action	Effective in short-term
Alternative GW-2 - Limited Action	Effective in short-term; Provides a means of monitoring compliance with remedial action objectives
Option GW-2A - Long-Term Monitoring	Effective in short-term; Provides means of monitoring ground water, surface water and sediment quality to ensure future degradation does not occur which would result in ecological impacts
Option GW-2B - Deed Restrictions	Effective in short-term; Minimizes potential human exposures to contaminated ground water
Alternative GW-3 - Containment	Increased short-term risks associated with construction can be minimized through use of personnel protective equipment; Meets remedial action objectives
Option GW-3A - Capping	See GW-3
Option GW-3B - Sheet Piling	See GW-3
Alternative GW-4 - Extraction/Treatment Discharge	Effective in short-term; Meets remedial action objectives
Option GW-4A - Extraction	Increased short-term risks associated with extraction well installation can be minimized through use of personnel protective equipment
Option GW-4B - Air Stripping	Minimal short-term risks associated with implementation
Option GW-4C - UV Oxidation	Minimal short-term risks associated with implementation; requires handling of chemical supplies
Option GW-4D - Precipitation	Minimal short-term risks associated with implementation; requires handling of chemical supplies and residual sludge
Option GW-4E - Membrane Microfiltration	Minimal short-term risks associated with implementation; requires handling of residual sludge
Option GW-4F - Discharge to Surface Water	Effective in short-term

TABLE 4-28
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVE
IMPLEMENTABILITY
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternativ GW-1 - No Action	Requires no implementation other than a five-year review; Would not limit the implementation of other remedial actions
Alternativ GW-2 - Limited Action	Fairly easily implemented; Would not limit the implementation of other remedial actions
Option GW-2A - Long-Term Monitoring	Long-term monitoring program easily implemented
Option GW-2B - Deed Restrictions	Deed restrictions would have to be incorporated in the base closure property transfer process; Limitation of future on-site ground water use is not expected to prevent future recreational/conservational use of the site.
Alternative GW-3 - Containment	Requires a significant construction effort although materials are readily available; Containment features could be impacted if future remedial actions are required; Would not prevent future use of the site for recreation or conservation
Option GW-3A - Capping	Site preparation would entail clearing of the site vegetation and regrading; Some movement and recompaction of existing waste materials would be required; Provision of protection along the shoreline would also be required
Option GW-3B - Sheet Piling	Installation can be adversely affected by the presence of subsurface boulders or cobbles; The presence of a vertical barrier could enhance active ground water remediation measures and would have to be considered in the design and implementation of other remedial measures
Alt rnative GW-4 - Extraction/Treatment Discharge	Relatively easy to implement, requiring installation of ground water extraction, treatment and discharge systems; Should not limit the implementation of other remedial actions
Option GW-4A - Extraction	Easy to implement, requiring the installation of extraction wells; Services and materials are readily available
Option GW-4B - Air Stripping	Easily implemented; Utilizes widely available treatment technology; Requires minimal operation and maintenance
Option GW-4C - UV Oxidation	Fairly easily implemented; Treatment system is not as simple to operate as Option GW-4B
Option GW-4D - Precipitation	Easily implemented; Utilizes widely available treatment technology; Requires monitoring and handling of sludge residual
Option GW-4E - Membrane Microfiltration	Fairly easily implemented; Treatment systems are not as widely available as Option GW-4D; Requires handling of sludge residual
Option GW-4F - Discharge to Surface Water	Easily implemented; Requires monitoring in complianc with discharge regulations

TABLE 4-29
COMPARISON AMONG GROUND WATER/LEACHATE ALTERNATIVE
COST
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT WORTH O&M COST (1)	TOTAL PRESENT WORTH (2)
Alternative GW-1 - No Action	--	--	--	Nominal (3)
Alternative GW-2 - Limited Action				
Option GW-2A - Long-Term Monitoring	--	$97,000	$1,500,000	$1,800,000
Option GW-2B - Deed Restrictions	--	--	--	Nominal (3)
Alternative GW-3 - Containment		-- See options below --		$3,800,000 to $11,000,000
Option GW-3A - Capping		-- See Table 4-13 --		$3,800,000 to $5,400,000
Option GW-3B - Sheet Piling	$4,400,000	$20,000	$310,000	$5,700,000
Alternative GW-4 - Extraction/Treatment Discharge		-- See options below --		$2,400,000 to $13,000,000
Option GW-4A - Extraction	$230,000	$28,000	$430,000	$790,000
Option GW-4B - Air Stripping	$57,000	$1,300	$20,000	$93,000
Option GW-4C - UV Oxidation	$250,000	$44,000	$670,000	$1,100,000
Option GW-4D - Precipitation	$180,000	$48,000	$730,000	$1,100,000
Option GW-4E - Membrane Microfiltration	$450,000	$550,000	$8,500,000	$11,000,000
Option GW-4F - Discharge to Surface Water	$5,800	$24,000	$370,000	$450,000

(1) - Based on 5% discount rate
(2) - Includes 20% contingency on all components
(3) - The only cost associated with the implementation of Alternative GW-1 would be that associated with conducting a five-year review of the no action decision. Deed restrictions would be implemented under the base closure property transfer process.

TABLE 4-30
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE SD-1 - NO ACTION
ALTERNATIVE SD-2 - LIMITED ACTION
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Wetlands/Water Resources--				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Since these alternatives do not impact coastal or on-shore wetland areas, they meet this ARAR.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredge or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Filling a Navigable Water	Applicable	Prohibits the discharge of dredged or fill material to a water of the United States if there is a practicable alternative which poses less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	Since these alternatives do not involve the discharge of dredged or fill material, they meet this ARAR.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making process which may impact water bodies, including wetlands. Measures to prevent, mitigate or compensate for losses of fish and wildlife will be given due consideration whenever a modification of a water body is proposed.	Since these alternatives do not involve modification of a water body, they meet this ARAR.

TABLE 4–30(Continued)
FEDERAL AND STATE LOCATION–SPECIFIC ARARs AND TBCs
ALTERNATIVE SD–1 – NO ACTION
ALTERNATIVE SD–2 – LIMITED ACTION
SITE 09 – ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Coastal Zones––				
	Coastal Zone Management Act (16 USC Section 1451 et seq.)	Applicable	Regulates activities affecting the coastal zone including lands thereunder and adjacent shoreline.	Since these alternatives do not involve activities which affect the coastal zone, they meet this ARAR.
STATE				
Wetlands––				
	Rhode Island Wetlands Laws (RIGL 2–1–18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh–water Wetlands Act – as amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Since these alternatives do not impact a wetland area, they meet this ARAR.
Coastal Zone––				
	Rhode Island Coastal Resources Management Law, (RIGL, Title 46, Chapter 23) and Regulations	Applicable	Creates Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources.	Since these alternatives do not involve regulated activities as specified under the Coastal Resources Management Program, they meet this ARAR.

TABLE 4-31
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE SD-3 - CONTAINMENT
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Wetlands/Water Resources--				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Will be applicable since sediment containment would impact coastal or on-shore wetland areas.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredge or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Filling a Navigable Water	Applicable	Prohibits the discharge of dredged or fill material to a water of the United States if there is a practicable alternative which poses less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	Will be applicable since sediment containment would impact wetland and water. If containment cannot be limited to within toeprint of existing landfill, mitigation of impacted wetlands may be required.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making process which may impact water bodies, including wetlands. Measures to prevent, mitigate or compensate for losses of fish and wildlife will be given due consideration whenever a modification of a water body is proposed.	If the implementation of a remedial action results in an impact to a water body, consultation with U.S. Fish and Wildlife Service, RIDEM, and other federal and state agencies involved in fish and wildlife matters is required. ARAR for containment construction.

TABLE 4-31 (Continued)
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE SD-3 - CONTAINMENT
SITE 09 - ALLEN HARBOR LANDFILL

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Coastal Zones--				
	Coastal Zone Management Act (16 USC Section 1451 et seq.)	Applicable	Regulates activities affecting the coastal zone including lands thereunder and adjacent shoreline.	Requires determination that containment construction activities are consistent to the maximum extent practicable with State Coastal Zone Management Plan.
STATE				
Wetlands--				
	Rhode Island Wetlands Laws (RIGL 2-1-18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh-water Wetlands Act - as amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Regulation will be applicable if implementation impacts a freshwater wetland area.
Coastal Zone--				
	Rhode Island Coastal Resources Management Law, (RIGL, Title 46, Chapter 23) and Regulations	Applicable	Creates Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources.	Since Allen Harbor Landfill is located in a coastal area, the Navy will coordinate with the Rhode Island Coastal Resources Management Council and will ensure that all actions are consistent, to the maximum extent practicable, with the Coastal Zone Management Plan.

TABLE 4-32
FEDERAL ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE SD-3 - CONTAINMENT
SITE 09 - ALLEN HARBOR LANDFILL

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
FEDERAL				
Construction	Migratory Bird Treaty Act (16 U.S.C. 703-712)	Applicable	Prohibits hunting, possessing, killing, or capturing of migratory birds, birds in danger of extinction, and those birds' eggs or nests.	Since construction activities during the breeding season may "take" birds or their nests, actions must be taken to avoid destroying nests during breeding season.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredged or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Wetland Filling	Applicable	Prohibits the discharge of dredged or fill material to waters of the United States unless no other practical alternatives are available which pose less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	If it is determined that a remedial action cannot be limited to areas within the toeprint of the existing landfill, mitigation of any impacted wetlands may be required.

TABLE 4-33
COMPARISON AMONG SEDIMENT ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternativ SD-1 - No Action	Does not provide any protection against disturbance of contaminated sediments or long-term monitoring of sediment quality; The limited areal extent of sediments at the toe of the landfill is expected to limit the actual threat to human health and the environment posed by the sediment contaminants; Meets ARARs/TBCs
Alternative SD-2 - Limited Action	Provides a mechanism for identifying changes in sediment quality which may result in future environmental impacts; Provides no protection against disturbance of existing sediment contamination; Effective in the short-term; Meets ARARs/TBCs
Alternative SD-3 - Containment	Provides protection against exposures by containing sediments and by eliminating environmental exposure pathway and potential disturbance of sediments; Effective in the long-term; May result in an increase in short-term risks; Meets ARARs/TBCs

TABLE 4-34
COMPARISON AMONG SEDIMENT ALTERNATIVES
COMPLIANCE WITH ARARS
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	CHEMICAL-SPECIFIC	LOCATION-SPECIFIC	ACTION-SPECIFIC
Alternative SD-1 - No Action	Not applicable	Meets criteria; Involves no actions which impact coastal or wetland areas	Not applicable
Alternative SD-2 - Limited Action	Not applicable	Meets criteria; Involves no actions which impact coastal or wetland areas	Not applicable
Alternative SD-3 - Containment	Not applicable	Implementation of construction activities would comply with criteria (i.e. wetland and coastal zone requirements); Mitigation of any impacted wetlands may be required	Would comply with action-specific ARARs applicable to construction activities

TABLE 4-35
COMPARISON AMONG SEDIMENT ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative SD-1 - No Action	Residual risk to the environment remains; Provides no long-term protection against storm events; 5-year review required
Alternative SD-2 - Limited Action	Residual risk to the environment remains; provides no long-term protection against storm events; Monitoring would identify any changes in sediment quality; 5-year review required
Alternative SD-3 - Containment	Effectiveness in the long-term based on containment features; Eliminates potential exposure pathways; 5-year review required

TABLE 4–36
COMPARISON AMONG SEDIMENT ALTERNATIVES
REDUCTION IN TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative SD–1 – No Action	Provides no reduction in sediment toxicity, mobility or volume through treatment
Alternative SD–2 – Limited Action	Provides no reduction in sediment toxicity, mobility or volume through treatment
Alternative SD–3 – Containment	Provides no reduction in sediment toxicity, mobility or volume through treatment; Reduces contaminant mobility through containment features

TABLE 4-37
COMPARISON AMONG SEDIMENT ALTERNATIVES
SHORT-TERM EFFECTIVENESS
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative SD-1 - No Action	Effective in short-term; Does not meet remedial response objectives
Alternative SD-2 - Limited Action	Effective in short-term; Does not meet remedial response objectives
Alternative SD-3 - Containment	Could result in increased short-term risks due to potential disruption of contaminated sediments; meets remedial response objectives

TABLE 4-38
COMPARISON AMONG SEDIMENT ALTERNATIVES
IMPLEMENTABILITY
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative SD-1 - No Action	Requires no implementation other than a five-year review; Would not limit the implementation of other remedial actions
Alternative SD-2 - Limited Action	Long-term monitoring program easily implemented; Would not limit the implementation of other remedial actions
Alternative SD-3 - Containment	Requires greatest implementation effort; Could affect the implementation of other remedial actions

TABLE 4-39
COMPARISON AMONG SEDIMENT ALTERNATIVES
COST
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT WORTH O&M COST (1)	TOTAL PRESENT WORTH (2)
Alternative SD-1 - No Action	--	--	--	Nominal (3)
Alternative SD-2 - Limited Action	--	$30,000	$460,000	$550,000
Alternative SD-3 - Containment	$430,000	$600	$9,100	$530,000

(1) - Based on 5% discount rate
(2) - Includes 20% contingency on all components
(3) - The only cost associated with the implementation of Alternative SD-1 would be that associated with conducting a five-year review of the no action decision.

TABLE 4-40
COST SENSITIVITY ANALYSIS
SITE 09 - ALLEN HARBOR LANDFILL

Item Varied (Minimum - Maximum)	Alternative	Minimum Cost	Maximum Cost
Discount Factor (10% - 3%)	Soil/Waste		
	S/W-2	$288,000	$519,000
	S/W-3A	$2,558,000	$2,797,000
	S/W-3B	$3,599,000	$3,896,000
	S/W-3C	$5,177,000	$5,474,000
Discount Factor (10% - 3%)	Ground Water		
	GW-2A	$1,099,000	$2,286,000
	GW-3B	$5,538,000	$5,782,000
	GW-4A	$593,000	$937,000
	GW-4B	$83,000	$99,000
	GW-4C	$801,000	$1,334,000
	GW-4D	$753,000	$1,333,000
	GW-4E	$6,808,000	$13,573,000
	GW-4F	$277,000	$567,000
Discount Factor (10% - 3%)	Sediment		
	SD-2	$337,000	$701,000
	SD-3	$526,000	$533,000

TABLE 5–1
DESCRIPTIONS OF GENERAL COMPREHENSIVE ALTERNATIVES
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE, RI

ACTION	DESCRIPTION
Alt rnative 1 – No Action	• No action
Alt rnative 2 – Limited Action	• Deed restrictions to limit future exposures to subsurface waste materials and contaminated ground water • Fencing to prevent human exposures to contaminated surface materials • Long–term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present increased ecological risks
Alternative 3 – Containment	• Landfill cap consisting of a native soil cap or single–barrier cap and stormwater discharge monitoring • Containment of landfill toe sediments • Deed restrictions to limit future exposures to subsurface waste materials, disruption of the capping system and exposures to contaminated ground water • Long–term monitoring of ground water, surface water and sediment quality to identify any future changes in site conditions which could present increased ecological risks
Alternative 4 – Containment with Ground Water Treatment	• Single–barrier cap and stormwater discharge monitoring • Sheet piling • Ground water extraction, air stripping, and chemical precipitation with discharge to Allen Harbor • Long–term ground water monitoring • Deed restrictions to limit future exposures to subsurface waste materials

TABLE 5-2
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 - No Action	Provides no overall protection of human health and the environment; Does not meet remedial action objectives; Not effective in the long-term
Alternative 2 - Limited Action	Provides protection of human health but not the environment; Does not address leachate seeps, potential ground water migration or potential exposures to surficial contaminants by ecological receptors; Not effective in the long-term
Alternative 3 - Containment	Protective of human health and the environment; Limits potential exposures to human receptors through physical containment and deed restrictions; Limits potential environmental impacts through physical containment of contaminated surface materials and sediments; Potential exposures and contaminant migration due to leachate seeps are minimized by presence of cap; Provides long-term monitoring to identify any potential environmental impacts due to ground water migration in the future
Alternative 4 - Containment with Ground Water Treatment	Protective of human health and the environment; Limits potential exposures to human receptors through physical containment and deed restrictions; Limits potential environmental impacts through physical containment of contaminated surface materials and sediments; Potential exposures and contaminant migration due to leachate seeps are minimized by presence of cap; Provides active treatment of ground water, thereby minimizing potential environmental impacts due to ground water migration in the future; Protection against contaminated ground water migration may not be permanent following treatment system discontinuation

TABLE 5-3
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
COMPLIANCE WITH ARARS
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	CHEMICAL-SPECIFIC	LOCATION-SPECIFIC	ACTION-SPECIFIC
Alternative 1 - No Action	Does not meet ARARs/TBCs applicable to soil; Ambient Water Quality Criteria (AWQC) exceeded in ground water but due to lack of ecological impacts definitely attributable to ground water discharge, modification of AWQC may be appropriate before application as ground water ARARs	Meets criteria; involves no actions which impact coastal or wetland areas	Not applicable Not applicable
Alternative 2 - Limited Action	Does not meet ARARs/TBCs applicable to soil; Ambient Water Quality Criteria (AWQC) exceeded in ground water but due to lack of ecological impacts definitely attributable to ground water discharge, modification of AWQC may be appropriate before application as ground water ARARs	Construction of fencing would comply with criteria (i.e. wetland and coastal requirements)	Would comply with action-specific ARARs applicable to monitoring and construction activities
Alternative 3 - Containment	Meets ARARs/TBCs applicable to soil through containment; Ambient Water Quality Criteria (AWQC) exceeded in ground water but due to lack of ecological impacts definitely attributable to ground water discharge, modification of AWQC may be appropriate before application as ground water ARARs	Cap construction and sediment containment would comply with criteria (i.e. wetland and coastal zone requirements); Mitigation of any impacted wetlands may be required	Would comply with action-specific ARARs applicable to monitoring, construction, stormwater discharge, landfill closure, and venting (as appropriate) activities
Alternative 4 - Containment with Ground Water Treatment	Meets ARARs/TBCs applicable to soil through containment; Ambient Water Quality Criteria (AWQC) exceeded in ground water but due to lack of ecological impacts definitely attributable to ground water discharge, modification of AWQC may be appropriate before application as ground water ARARs; Treatment alternatives selected to treat ground water contaminants which exceed AWQC	Cap construction, sheet piling installation, ground water extraction/treatment/ discharge system and sediment containment would comply with criteria (i.e. wetland and coastal zone requirements); Mitigation of any impacted wetlands may be required	Would comply with action-specific ARARs applicable to monitoring, construction, stormwater discharge, landfill closure, hazardous waste characterization and air discharge/venting activities

TABLE 5-4
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 - No Action	Residual risk to human health and the environment remains; Provides no long-term protection; 5-year review required
Alternative 2 - Limited Action	May be effective in the long-term in reducing risks to humans but residual risk to the environment remains; Provides no long-term protection against environmental exposures to surface contaminants, sediments or leachate seeps; Monitoring would identify any changes in ground water, surface water or sediment quality; 5-year review required
Alternative 3 - Containment	Effective in the long-term in eliminating exposures to surficial contaminants and sediment as well as leachate seeps; Long-term monitoring would provide a means of monitoring any changes in ground water, sediment or surface water quality which could result in measurable impacts to ecological receptors; 5-year review required
Alternative 4 - Containment with Ground Water Treatment	Effective in the long-term in eliminating exposures to surficial contaminants and sediment as well as leachate seeps; Ground water extraction and treatment would minimize potential impacts due to migration of contaminated ground water; Long-term ground water monitoring would provide a means of monitoring any changes in ground water once treatment is discontinued; Permanence in eliminating future re-contamination of ground water is not ensured once treatment is discontinued; 5-year review required

TABLE 5-5
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
REDUCTION IN TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 - No Action	Provides no reduction in contaminant toxicity, mobility or volume through treatment
Alternative 2 - Limited Action	Provides no reduction in contaminant toxicity, mobility or volume through treatment
Alt rnative 3 - Containment	Provides no reduction in contaminant toxicity, mobility or volume through treatment; Reduces contaminant mobility through containment features
Alternative 4 - Containment with Ground Water Treatment	Provides no reduction in soil/waste or sediment contaminant toxicity, mobility or volume through treatment Reduces ground water toxicity through treatment although re-contamination of ground water may occur following discontinuation of treatment

TABLE 5-6
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
SHORT-TERM EFFECTIVENESS
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 - No Action	Effective in short-term; However, remedial action objectives are not achieved
Alternative 2 - Limited Action	Effective in short-term; However, remedial action objectives are not achieved
Alternative 3 - Containment	Could result in increased short-term risks due to potential disruption of contaminated surficial materials and sediments; Remedial action objectives achieved
Alt rnative 4 - Containment with Ground Water Treatment	Could result in increased short-term risks due to potential disruption of contaminated surficial materials and sediments and operation of on-site treatment systems; Remedial action objectives achieved

TABLE 5-7
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
IMPLEMENTABILITY
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 - No Action	Requires no implementation other than a five-year review; Would not limit the implementation of other remedial actions
Alternative 2 - Limited Action	Long-term monitoring program easily implemented; Would not limit the implementation of other remedial actions; Would limit feasibility of utilizing the site for future recreational uses, in accordance with the Base Reuse Plan
Alternative 3 - Containment	Implementable within a one- to two-year period; materials and services readily available; Could complement future recreational or conservational site use; Presence of cap and sediment containment could impact implementation of other remedial actions, if required
Alternative 4 - Containment with Ground Water Treatment	Implementable but requires extended operational period; Materials and services readily available; Could complement future recreational or conservational site use; Presence of cap and sediment containment could impact implementation of other remedial actions, if required

TABLE 5-8
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
COST
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE, RI

ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT WORTH O&M COST [1]	TOTAL PRESENT WORTH [2]
Alternative 1 – No Action	--	--	--	Nominal [3]
Alternative 2 – Limited Action [4]	$61,000	$116,000	$1,800,000	$2,200,000
Alternative 3 – Containment [5]				
Native Soil Cap	$2,400,000	$118,000	$1,800,000	$5,000,000
Single-Barrier Hybrid Cap	$2,700,000	$122,000	$1,900,000	$5,600,000
Alternative 4 – Containment with Ground [6] **Water Treatment**	$7,200,000	$240,000	$3,700,000	$13,000,000

Note: Costs are presented based on a combination of individual alternative costs as presented in Section 4 tables.
(1) – Based on 5% discount rate
(2) – Includes 20% contingency on all components
(3) – The only cost associated with the implementation of Alternative 1 would be that associated with conducting a five-year review of the no action decision.
(4) – For costing purposes, Alternative 2 consists of Alternatives S/W-2 and GW-2A
(5) – For costing purposes, Alternative 3 consists of Alternatives SD-3 and GW-2A combined with Alternatives S/W-3A or S/W-3B
(6) – For costing purposes, Alternative 4 consists of Alternatives S/W-3B, GW-2A, GW-3B, GW-4A, GW-4B, GW-4D and GW-4F

APPENDIX A

IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

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APPENDIX A

IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

A.1 Introduction

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA, 1986), and the NCP (1990) require that all remedial response actions attain or exceed applicable or relevant and appropriate requirements of Federal and more stringent promulgated requirements of State environmental statute(s). The NCP defines applicable requirements as "those cleanup standards, standards of control, other substantive environmental protection requirements or criteria, or limitations promulgated under federal environmental or state environmental facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances found at a CERCLA site." Relevant and appropriate requirements are defined in the NCP as "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at the CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site."

To-Be-Considered materials (TBCs) are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of potential ARARs. However, in many circumstances TBCs may be considered along with ARARs in determining the necessary level of cleanup for protection of health or the environment.

Current EPA CERCLA guidance calls for a preliminary identification of potential ARARs during the RI scoping phase to assist in initial identification of remedial alternatives. Early identification also facilitates communications with support agencies to evaluate ARARs, and may help planning of field activities. Because of the iterative nature of the RI/FS process, ARAR identification continues throughout the RI/FS as better understanding is gained of the site conditions, site contaminants, and remedial action alternatives. Findings of the Phase I RI aided in the selection of ARARs as presented in Volume II of the Phase II RI/FS Work Plan (TRC, 1992). ARARs were further evaluated in the Initial Screening of Alternatives Report (TRC, May 1993b). This section revisits the information provided in that report, updating it on the basis of the specific information related to Site 09, as addressed herein, as well as on the basis of evolving regulatory requirements.

ARARs may be categorized as: 1) chemical-specific requirements, which may define acceptable exposure levels and, therefore, be used in establishing preliminary remediation goals; 2) location-specific requirements, which may set restrictions on activities within specific locations such as floodplains or wetlands; and 3) performance, design or other action-specific requirements, which may set controls or restrictions for particular treatment and disposal activities related to the management of hazardous wastes. The documents "CERCLA Compliance With Other Laws Manual" (USEPA, 1988b), and "CERCLA Compliance with Other Laws Manual: Part II. Clean Air Act and Other Environmental Statutes and State Requirements" (USEPA, 1989b), contain detailed information on identifying and complying with ARARs. In addition, Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991a) provides guidance on the use of ARARs for the development of preliminary remediation goals (PRGs).

A.2 Approach

This evaluation focuses on the identification of potential chemical-specific ARARs/TBCs which will guide the development of PRGs at Site 09. Preliminary location-specific and action-specific ARARs/TBCs are also evaluated herein, but are further evaluated with respect to the individual remedial alternatives in the detailed alternative analysis portion of this report.

To determine the chemical-specific requirements which may be applicable to remediation at Site 09 (i.e., to identify preliminary remediation goals (PRGs) and chemical-specific ARARs which may be applicable to certain remedial actions), an evaluation of federal and State of Rhode Island chemical-specific ARARs was conducted. Those federal and state chemical-specific ARARs considered to potentially be applicable or relevant and appropriate to remedial actions at Site 09 have been compiled, as presented in Tables A-1 and A-2.

A.3 Potential Federal Chemical-Specific ARARs/TBCs

Potential federal chemical-specific ARARS and TBC criteria are presented in Table A-1. Chemical-specific ARARs/TBCs which may be applicable to the development of preliminary remediation goals for the various media at the site are addressed by media below. Following this discussion is a presentation of potential chemical-specific ARARs/TBCs which may be considered in the evaluation of specific remedial actions at the site.

A.3.1 Ground Water

Ground water at NCBC Davisville is not a current source of drinking water, and ground water at Site 09 is classified as GB. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991a) provides guidance on the development of PRGs for ground water. Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs), non-zero maximum contaminant level goals (MCLGs), and state drinking water standards are common ARARs and therefore PRGs for ground water that is a current or potential source of drinking water. For chemicals without MCLs, state standards, or non-zero MCLGs, ambient water quality criteria (AWQC) may be potentially relevant and appropriate for ground water when that ground water discharges to surface water that is used for fishing or shellfishing. If the aquifer being addressed is not a potential source of drinking water, then MCLs, MCLGs, state drinking water requirements, or other health-based levels generally are not appropriate as PRGs. Instead, environmental considerations (i.e., effects on biological receptors) and prevention of plume expansion generally determine cleanup levels (USEPA, 1991a).

Additional studies are being conducted to quantify ground water quality at the Allen Harbor Landfill site. These studies are being undertaken to support a determination that the ground water at the site would be unsuitable for potable use due to brackishness, regardless of the potential contribution of landfill source contaminants. Due to the site's proximity to Allen Harbor, it is expected that ground water quality may be affected by salt water intrusion. A preliminary evaluation of the potential brackishness of the water based on the presence of sodium indicates the ground water is brackish and would not be suitable as a potential source of drinking water. Sodium levels in the Site 09 monitoring wells average 28 ppm for shallow wells and 70 ppm for deep wells. The maximum sodium level detected was 230 ppm in well 09-MW7D. Sodium levels in surface water samples SW9 and SW10 collected from Allen Harbor adjacent to the toe of the landfill were 289 ppm and 1,750 ppm, respectively. While there is no MCL or MCLG for sodium, a Drinking Water Equivalent Level (DWEL) guidance level of 20 mg/l (ppm) has been established. The DWEL is defined as a lifetime exposure concentration protective of adverse, non-cancer health effects, that assumes all of the exposure to the contaminant is from a drinking water source. Site averages exceed this guidance level. Therefore, for the purposes of this evaluation, AWQC, as promulgated under the Clean Water Act, environmental considerations (i.e., effects on biological receptors) and prevention of plume expansion will be considered further in the development of PRGs for ground water.

AWQC are developed to be protective of human health based on exposure from drinking the water and consuming aquatic organisms or based on fish consumption alone and to be protective of aquatic organisms alone. Since Allen Harbor would not be used as a source of potable water but fish from Allen Harbor could be consumed, the AWQC based on fish consumption alone will be considered. The AWQC for marine life will also be considered.

AWQC without modification are not relevant and appropriate in selecting cleanup levels in ground water (USEPA, 1988b). For example, consumption of fish is not a concern for direct ground water exposures. If ground water discharges to surface water and contaminants are affecting aquatic life, AWQC should be consulted and may be relevant and appropriate. Because AWQC do not incorporate such factors as detection limits, technical feasibility of achieving standards, or cost, the cleanup levels for a site may have to be adjusted from the AWQC value (USEPA, 1988c).

Federal Resource Conservation and Recovery Act Alternate Concentration Limits (ACLs) established under 40 CFR 264.94 are relevant and appropriate to the development of preliminary remediation goals where MCLs are not relevant and appropriate. In such circumstances, exposure-based ACLs would be developed. CERCLA §121(d)(2)(B)(ii) provides a set of three additional conditions limiting the use of ACLs at Superfund sites in lieu of otherwise applicable limitations. ACLs can only be used as cleanup levels if the following conditions are met:

- The ground water has known or projected points of entry into surface water, which is a reliable distance from the facility boundary;

- There will be no statistically significant increase at the 95 percent confidence level of constituent concentrations occurring in the surface water in the discharge zone or at any point where constituents are expected to accumulate;

- Institutional controls will be implemented that will preclude human exposure to ground water contaminants between the facility boundary and the point of entry into the surface water.

Determining statistically significant increases in surface water should include the following steps, as appropriate:

- Samples of surface water should be collected during base flow conditions;

- Surface water samples should be collected within the discharge zone of the ground water contaminant plume;

- Sediment and biota samples should be collected with surface water samples to determine if contaminants are accumulating in the sediments or biota;

- Contaminant degradation should be considered, and analysis for degradation products conducted;

- If concentrations in shallow and deep ground water adjacent to the surface water body are detectable, then concentrations in the discharge zone should be compared to concentrations in a background area of the surface water body;

- If ACLs are established for a site, periodic surface water sampling should be conducted.

A.3.2 Soils

The Toxic Substances Control Act provides PCB cleanup levels for solid surfaces and soils where spills occurred after May 4, 1987. These levels may be relevant and appropriate for Site 09, since PCBs were detected in soils. In addition, the Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02) will represent TBC criteria for lead in soils.

A.3.3 Surface Water

AWQC may be applicable to the development of PRGs for surface water.

A.3.4 Sediments

No chemical-specific ARARs/TBCs were identified.

A.3.5 Chemical-Specific ARARs Potentially Applicable to Remedial Actions

Chemical-specific federal ARARs/TBCs which are applicable to the implementation of certain remedial actions include Ambient Water Quality Criteria (AWQC) and Effluent Discharge Limitations, both promulgated under the Clean Water Act, which represent potential chemical-specific ARARs for alternatives which involve discharges to surface waters.

The Toxic Characteristic Leachate Parameter (TCLP) maximum concentrations (40 CFR 261.24) and the land disposal restrictions (40 CFR 268) will be applicable to any action which requires a hazardous waste determination and disposal option evaluation.

Sections of the Clean Air Act which establish maximum concentrations for particulates and fugitive dust emissions, emissions limitations for new sources, and emissions limitations for hazardous air pollutants, are considered potential chemical-specific ARARs for remedial alternatives which impact ambient air.

A.4 Potential Rhode Island Chemical-Specific ARARs/TBCs

A.4.1 Ground Water

Potential Rhode Island chemical-specific ARARs and TBC criteria are presented in Table A-2. As discussed in Section A.3.1, Rhode Island Public Drinking Water Regulations are not considered to be ARARs for Site 09 due to the brackishness of the ground water adjacent to Allen Harbor. However, the Rhode Island Water Quality Standards, established under the RI Water Pollution Control Law (RIGL, Title 46, Chapter 12), are potentially relevant and appropriate (similar to the federal AWQC) to the development of ground water PRGs due to the potential for discharge of ground water to surface water.

A.4.2 Soil

Rhode Island's Rules and Regulations for Solid Waste Management Facilities define solid wastes as including wastes which contain a concentration of 10 ppm or greater PCBs. The Rules and Regulations for Hazardous Waste Management define Type 6 - extremely hazardous waste as including wastes which contain a concentration of 50 ppm or greater PCBs. These regulations may be relevant and appropriate to the establishment of a PRG for PCBs in site soils. RIDEM and the Rhode Island Department of Health-Risk Assessment consider a safe lead level in soil (total) as under 300 ppm, a TBC in the identification of PRGs at Site 09.

A.4.3 Surface Water

Rhode Island Water Quality Standards, established under the RI Water Pollution Control Law (RIGL, Title 46, Chapter 12), may be applicable as PRGs to surface water.

A.4.4 Sediment

No chemical-specific ARARs/TBCs were identified for sediment.

A.4.5 Chemical-Specific ARARs Potentially Applicable to Remedial Actions

Chemical-specific ARARs/TBCs which may be applicable to the implementation of certain remedial actions include the RI Clean Air Act (RI Title 23, Chapter 23) which establishes maximum ambient levels for criteria pollutants under the Air Pollution Control Regulation Standards. These levels constitute potential chemical-specific ARARs for remedial alternatives which emit pollutants into the air.

A.5 Potential Location-Specific ARARs/TBCs

A site's location is a fundamental determinant of its impact on human health and the environment. Location-specific ARARs are restrictions placed on the concentrations of hazardous substances or the conduct of activities solely because they are in a specific location (U.S. EPA, 1988b).

A.5.1 Potential Federal Location-Specific ARARs/TBCs

Federal location-specific ARARs and TBCs potentially applicable to the Site 09 are presented in Table A-3. Wetlands/water resources regulations, including Executive Orders 11988 and 11990, Statement of Proceedings of Floodplain Management and Wetlands Protection, the Clean Water Act Section 404 Requirements for Discharge of Dredge or Fill Material and the Rivers and Harbors Act Prohibition of Filling a Navigable Water will apply to any remedial action which impacts coastal or on-shore wetlands areas. The Fish and Wildlife Coordination Act of 1958 Protection of Wildlife Habitats may require consultation with U.S. Fish and Wildlife Service, RIDEM, or other federal or state agencies involved in fish and wildlife matters if the implementation of a remedial action results in an impact to a water body.

Coastal area and harbor protection regulations, including the Coastal Zone Management Act of 1972, which regulates land use along coastal areas of the U.S. are also potential ARARs for remedial alternatives at Site 09. The Coastal Zone Management Act requires that all activities conducted in a coastal zone are consistent with the State Coastal Zone Management Plan to the maximum extent practicable.

The Endangered Species Act of 1973, which restricts activities in areas inhabited by registered endangered species, is not considered to be a potential ARAR for Site 09 based on the conclusion of an endangered species survey conducted in 1989 by RIDEM (RIDEM, 1989).

Based on the results of a cultural resources survey conducted at the NCBC facility, as described in Cultural Resource Assessment for Base Closure and Realignment, Redevelopment and Reuse at the Naval Construction Battalion Center, Davisville, Rhode Island, as prepared by Ecology and Environment, Inc. and dated November 1993, the National Historic Preservation Act of 1966 and the Archaeological and Historic Preservation Act of 1974 are not considered to be potential ARARs for remedial actions at Site 09. The cultural resource survey report concluded that the majority of surficial deposits at the facility have been severely impacted by extensive land moving activities conducted by the Navy, and did not recommend archaeological surveys or identify any historic properties at any areas in the immediate vicinity of Site 09.

To determine the potential applicability of the Farmland Protection Policy Act, the U.S. Department of Agriculture Important Farmlands Map for Kent County was reviewed. This map, developed on the basis of soil survey information, indicates that limited areas designated as Prime

Farmland and Additional Farmland of Statewide Importance are located in the general vicinity of the NCBC Davisville facility but do not encompass Site 09. Therefore, farmland protection regulations are not considered to be applicable to remedial actions at Site 09.

A.5.2 Potential State Location-Specific ARARs/TBCs

State location-specific ARARs/TBCs potentially applicable to the Site 09 are presented in Table A-4. Rhode Island defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state under the Rhode Island Wetlands Laws, which are potential ARARs if remedial actions impact a wetland area.

Rhode Island Coastal Resources Management Law and Regulations provides the basis for establishment of the Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources. Based on Site 09's location along Allen Harbor, actions conducted at the site must be consistent with the Coastal Resources Management Plan to the degree practicable.

A.6 Potential Action-Specific ARARs/TBCs

Based on the identification of contaminants in various on-site media at the Site 09, remediation activities may be required and numerous state and federal requirements could apply to the implementation of these activities. As discussed previously, potential action-specific ARARs/TBCs cannot be well-defined until remedial alternatives are developed and response actions defined. Action-specific ARARs will be defined in more detail in the detailed analysis of alternatives (Section 4 of this report).

A.6.1 Potential Federal Action-Specific ARARs/TBCs

Numerous federally promulgated action-specific ARARs and TBC criteria could potentially affect the implementation of remedial measures. A preliminary evaluation of federal regulatory requirements potentially applicable to remedial activities at Site 09 is presented in Table A-5.

A significant determination at this point in the ARAR identification process is the determination of the applicability or relevance and appropriateness of RCRA closure requirements. RCRA closure requirements include clean closure requirements (removal and decontamination) or landfill closure requirements. This discussion focuses on landfill closure requirements.

RCRA requirements are applicable to a Superfund remedial action if the following conditions are met:

- The waste is a RCRA hazardous waste (referred to herein as Condition A), and either:
- The waste was initially treated, stored or disposed of after the effective date of the particular RCRA requirement (referred to herein as Condition B); or
- The activity at the CERCLA site constitutes treatment, storage or disposal, as defined by RCRA (referred to herein as Condition C).

Therefore, for RCRA requirements to be applicable, Condition A <u>and</u> either of Condition B or Condition C must be met. The applicability of each of these conditions to Site 09 is presented in the following paragraphs.

<u>Condition A</u> - For RCRA requirements to be applicable, a Superfund waste must be determined to be a listed or characteristic hazardous waste under RCRA. While wastes such as solvents were reportedly disposed of on-site, the exact sources and types of wastes disposed of have not been confirmed and, therefore, the disposal of listed or characteristic wastes cannot be confirmed. Therefore, Condition A has not been met, based on available information.

<u>Condition B</u> - Another condition to the applicability of a RCRA requirement is that the hazardous waste was treated, stored or disposed of after the effective date of RCRA (November 19, 1980). Since the last disposal of wastes on-site occurred before the effective date of RCRA, Condition B has not been met.

<u>Condition C</u> - RCRA requirements are also applicable if the CERCLA action itself constitutes treatment, storage or disposal under RCRA. Capping activities do not constitute hazardous waste treatment storage, or disposal. Therefore, Condition C has not been met.

Since none of the conditions described above are met at Site 09, RCRA requirements are not applicable to remedial actions. However, they can be considered to be relevant and appropriate if the source or prior use of a CERCLA waste is not identifiable but the waste is similar in composition to a known, listed RCRA waste. The circumstances of the release, including the hazardous properties of the waste, its composition and matrix, the characteristics of the site, and the nature and purpose of the requirement itself are also considered in determining if a RCRA requirement is relevant and appropriate. Based on the reported disposal of wastes such as preservatives, paint thinners, degreasers, PCBs and contaminated fuel oils, which are expected to be sufficiently similar to known, listed RCRA wastes but whose exact source cannot be defined, RCRA requirements are considered to be relevant and appropriate to the closure of Site 09.

When RCRA closure requirements are not applicable but are relevant and appropriate to a site, a hybrid approach to closure may be acceptable. A hybrid approach to closure is appropriate when residual contamination potentially poses a direct contact threat but does not pose a threat to ground water. A hybrid closure could consist of a cap to address the direct contact threat but an impermeable cap would not necessarily be required. Institutional controls and long-term monitoring may be appropriate when hybrid closure is used.

A.6.2 Potential State Action-Specific ARARs/TBCs

The State of Rhode Island has promulgated regulations similar to those of the federal government. A preliminary evaluation of potential state action-specific ARARs which may be applicable to remedial activities at Site 09 is presented in Table A-6. As described in Section A.6.1, hazardous waste landfill closure requirements have been determined to be relevant and appropriate to remedial actions at Site 09. However, state solid waste landfill closure requirements are retained as being potentially relevant and appropriate should a hybrid RCRA cap be evaluated. The state solid waste landfill closure requirements are more stringent than federal solid waste (Subtitle D) landfill closure requirements.

TABLE A-1
FEDERAL CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Ground Water--				
	Resource Conservation and Recovery Act, Subpart F (40 CFR 264.94) Ground Water Protection Standards, Alternate Concentration Limits	Relevant and Appropriate	Allows for the development of alternate concentration limits (ACLs) for facilities which treat, store or dispose of hazardous waste when the characteristics of the ground water (e.g., high salinity) limit the application of Maximum Contaminant Levels or health-based criteria. Exposure-based ACLs may be developed which take into consideration potential adverse effects on ground water quality and hydraulically-connected surface water quality.	Ground water alternate concentration limits, although currently undeveloped, may be relevant and appropriate to the development of site-specific remediation levels.
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	To be Considered	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC, with modification, may be relevant and appropriate to the development of PRGs for ground water based on the potential discharge of ground water to surface water that is used for fishing.
Surface Water --				
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	Relevant and Appropriate or Applicable	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC are relevant and appropriate to the development of PRGs for surface water. AWQC will also be applicable to remedial alternatives which involve discharges to surface water.
Soils/Surfaces--				
	Toxic Substances Control Act (40 CFR 761.125)	Relevant and Appropriate	Establishes PCB cleanup levels for soils and solid surfaces.	Applicable to spills of materials containing PCBs at concentrations of 50 ppm or greater that occurred after May 4, 1987. While not applicable to Site 09, these requirements are relevant and appropriate.
	Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02)	To Be Considered	Sets forth an interim soil cleanup level for lead at 500 to 1000 ppm.	Will be considered with respect to soil lead contamination.

TABLE A-1 (continued)
FEDERAL CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Soils/Surfaces (cont.)--				
	Toxicity Characteristic (40 CFR 261.24)	To be determined	Establishes maximum concentrations of contaminants for the toxicity characteristic using the test method described in 40 CFR 261 Appendix II.	Applicable where wastes produced as a byproduct of a remedial action require handling as a hazardous waste on the basis of the Toxic Characteristic Leachate Parameter (TCLP) analysis.
	Land Disposal Restrictions (40 CFR 268)	To be determined	Establishes maximum concentrations of contaminants on the basis of which hazardous wastes are restricted from land disposal.	This regulation will be applicable to remedial alternatives which utilize land disposal of hazardous waste.
Air--				
	Clean Air Act (40 CFR 50) National Ambient Air Quality Standards (NAAQS)	To be determined	Establishes maximum levels for pollutants and particulates within air quality control districts.	Potential ARARS for alternatives involving remedial actions which impact ambient air (i.e. incinerators, soil venting, etc.).
	Clean Air Act (40 CFR 60) New Source Performance Standards (NSPS)	To be determined	Establishes emissions limitations for new sources.	Potential ARARS for alternatives involving treatment methods which emit pollutants.
	Clean Air Act (40 CFR 61) National Emissions Standard for Hazardous Air Pollutants	To be determined	Establishes emissions standards for hazardous air pollutants.	Potential ARARS for alternatives involving treatment methods which emit hazardous air pollutants.

TABLE A-2
STATE CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Ground Water --				
	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	To be determined	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	WQS, with modification, may be relevant and appropriate to the development of PRGs for ground water based on the potential discharge of ground water to surface water that is used for fishing.
Surface Water --				
	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	Relevant and Appropriate or Applicable	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	WQS are relevant and appropriate to the development of PRGs for surface water. WQS will also be applicable for remedial alternatives which involve discharges to surface water.
Soils/Surfaces--				
	Lead Soil Cleanup Standard (Guidance)	To Be Considered	RIDEM and the Rhode Island Department of Health-Risk Assessment consider a safe lead level in soil (total) to be under 300 ppm.	To be considered with respect to lead soil contamination.
	RI Hazardous Waste Management Act of 1987 (RIGL 23-19.1 et seq.) Rules and Regulations for Hazardous Waste Management	Relevant and Appropriate or Applicable	Defines Type 6 – Extremely hazardous waste as including wastes which contain PCBs at a concentration of 50 ppm or greater or showing 10 $\mu g/100\ cm^2$ or greater as measured by a standard wipe test.	Relevant and appropriate to the development of PRGs for soil. Will be applicable for remedial alternatives which involve handling of materials which meet the definition of a hazardous waste.
	Rules and Regulations for Solid Waste Management Facilities	Relevant and Appropriate or Applicable	Defines solid waste as including any soil, debris or other material with a concentration of PCBs of 10 ppm or greater or containing 2 $\mu g/100\ cm^2$ or greater as measured by a standard wipe test.	Relevant and appropriate to the development of PRGs for soil. Will be applicable for remedial alternatives which involve handling of materials which meet the definition of a solid waste.
Air--				
	RI Clean Air Act (RIGL Title 23, Chapter 23) Air Pollution Control Regulation Standards	To be determined	Establishes maximum ambient levels for criteria pollutants.	Potential ARARs for remedial alternatives involving treatment methods which emit criteria pollutants.

TABLE A–3
FEDERAL LOCATION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Wetlands/Water Resources––				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long– and short–term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Will be applicable to remedial alternatives which impact coastal or on–shore wetland areas.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredge or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Filling a Navigable Water	Applicable	Prohibits the discharge of dredged or fill material to a water of the United States if there is a practicable alternative which poses less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	Will be applicable to remedial alternatives which impact wetlands and waters, or permit degradation of water.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision–making process which may impact water bodies, including wetlands. Measures to prevent, mitigate or compensate for losses of fish and wildlife will be given due consideration whenever a modification of a water body is proposed.	If the implementation of a remedial action results in an impact to a water body, consultation with U.S. Fish and Wildlife Service, RIDEM, and other federal and state agencies involved in fish and wildlife matters is required.

TABLE A-3 (continued)
FEDERAL LOCATION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Coastal Zones--				
	Coastal Zone Management Act (16 USC Section 1451 et seq.)	Applicable	Regulates activities affecting the coastal zone including lands thereunder and adjacent shoreline.	For remedial actions in a coastal zone, requires determination that all activities are consistent to the maximum extent practicable with State Coastal Zone Management Plan.

TABLE A–4
STATE LOCATION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Wetlands––				
	Rhode Island Wetlands Laws (RIGL 2–1–18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh–water Wetlands Act – as amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Regulation will be applicable if implementation of a remedial action impacts a wetland area.
Coastal Zone––				
	Rhode Island Coastal Resources Management Law, (RIGL, Title 46, Chapter 23) and Regulations	Applicable	Creates Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources.	Since Allen Harbor Landfill is located in a coastal area, the Navy will coordinate with the Rhode Island Coastal Resources Management Council and will ensure that all actions are consistent, to the maximum extent practicable, with the Coastal Zone Management Plan.

TABLE A–5
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Drainage/ Discharge	Clean Water Act (40 CFR 122–125) National Pollutant Discharge Elimination System (NPDES) Permit Requirements	Applicable	Permits contain applicable effluent standards (i.e. technology– and/or water quality–based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste from industrial facilities.	Any storm water drainage improvements would be designed to provide compliance with these regulations and drainage would be monitored in compliance with these regulations.
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	Relevant and Appropriate	Non–enforceable guidelines established for the protection of human health and/or aquatic organisms. These guidelines are used by states to set water quality standards for surface water.	AWQC will be applicable to remedial alternatives which involve discharges to surface water.
Capping/ Monitoring	Migratory Bird Treaty Act (16 U.S.C. 703–712)	Applicable	Prohibits hunting, possessing, killing, or capturing of migratory birds, birds in danger of extinction, and those birds' eggs or nests.	Since construction activities during the breeding season may "take" birds or their nests, actions must be taken to avoid destroying nests during breeding season.
	Clean Water Act Section 404 (40 CFR 230.10) Requirements for Discharge of Dredged or Fill Material and Rivers and Harbors Act (Section 10) Prohibition of Wetland Filling	Applicable	Prohibits the discharge of dredged or fill material to waters of the United States unless no other practical alternatives are available which pose less of an adverse impact on the aquatic ecosystem or if it causes significant degradation of the water. Rivers and Harbors Act prevents filling of a navigable water.	If it is determined that a remedial action cannot be limited to areas within the toeprint of the existing landfill, mitigation of any impacted wetlands will be required.

TABLE A–5 (continued)
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Capping/ Monitoring (cont.)	RCRA (40 CFR 264) Subtitle C Requirements:	Relevant and Appropriate	Outlines specifications and standards for design, operation, closure and monitoring of performance for hazardous waste storage, treatment and disposal facilities.	Substantive RCRA requirements will be met and adhered to on–site if appropriate, based on the specific remedial action.
	• 40 CFR 264.10–264.18 Subpart B – General Facility Standards	Relevant and Appropriate	General requirements regarding waste analysis, security, training, inspections, and location applicable to a facility which stores, treats or disposes of hazardous wastes (a TSDF facility).	This regulation may be applicable to remedial actions which address a waste which is a listed or characteristic waste under RCRA and which constitute current treatment, storage, or disposal as certified by RCRA.
	• 40 CFR 264.30–264.37 Subpart C – Preparedness and Prevention	Relevant and Appropriate	Requirements applicable to the design and operation, equipment, and communications associated with a TSDF facility, and to arrangements with local response departments.	This regulation may be applicable to remedial actions which address a waste which is a listed or characteristic waste under RCRA and which constitute current treatment, storage, or disposal as certified by RCRA.
	• 40 CFR 264.50–264.56 Subpart D – Contingency Plan and Emergency Procedures	Relevant and Appropriate	Emergency planning procedures applicable to a TSDF facility.	This regulation may be applicable to remedial actions which address a waste which is a listed or characteristic waste under RCRA and which constitute current treatment, storage, or disposal
	◦ 40 CFR 264.90–254.101 Subpart F – Ground Water Protection	Relevant and Appropriate	Ground water monitoring/corrective action requirements; dictates adherence to MCLs unless ACLS are appropriate and establishes points of compliance.	Monitoring standards will be met.

TABLE A–5 (continued)
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Capping/ Monitoring (cont.)	• 40 CFR 264.110–118 Subpart G – Closure/Post Closure Requirements	Relevant and Appropriate	Establishes requirements for the closure and long–term management of a hazardous disposal facility.	Relevant and appropriate standards and requirements will be met.
	• 40 CFR 264.301–264.310; Subpart N – Landfill Requirements	Relevant and Appropriate	Placement of cap over hazardous waste requres a cover designed and constructed to comply with regulations. Installation of final cover to provide long–term minimization of infiltration. Restricts post–closure use of property as necessary to prevent damage to cover.	Cap design will meet relevant and appropriate requirements.
	• RCRA Proposed Rule 52 FR 8712, 53 FR 51446 Proposed Amendments for Landfill Closures	To Be Considered	Provides an option for the application of alternate closure and post–closure requirements based on a consideration of site–specific conditions including exposure pathways of concern.	Cap and post–closure monitoring will be designed taking into account exposure pathways of concern. Provides basis for consideration of a hybrid RCRA cap.
	• EPA Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments (EPA 530–SW–89–047)	To Be Considered	EPA Technical Guidance for landfill covers. Presents recommended technical specifications for multilayer landfill cover design.	Cap design will consider these standards.

TABLE A–5 (continued)
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air	Clean Air Act (40 CFR 60) New Source Performance Standards (NSPS) Proposed Subpart WWW 56 FR 24468–24528 (5/30/91)	To Be Considered	Requires Best Demonstrated Technology (BDT) for new sources, and sets emissions limitations. Proposed Subpart WWW sets a performance standard for non–methane organic compounds (NMOC) emissions of 150 Mg/yr (167 tpy) for existing municipal solid waste landfills.	These standards should be considered if a landfill gas management system is required.
	Clean Air Act (40 CFR 61) National Emissions Standards for Hazardous Pollutants (NESHAP)	To Be Considered	Establishes emissions limitations for hazardous air pollutants and sets forth regulated sources of those pollutants.	Although EPA has not promulgated final Maximum Achievable Control Technology (MACT) standards for municipal landfills, the lead agency should use air control technology to control emissions of hazardous air pollutions. MACT standards prescribe technology that is used by the best 12% of industries in the source category.
	Clean Air Act, Section 5 171 through 178, 42 USC §§ 7471–7478 (Requirements for Non–Attainment Areas)	Applicable or Relevant and Appropriate (Depending on Modelling Results)	RI has adopted State Implementation Plan (SIP) requirements approved and enforcable by EPA which meet the New Source Review (NSR) requirement of the CAA. These provisions require that new or modified major sources of VOCs defined as a source which has the potential to emit 50 tpy install equipment to meet Lowest Available Emissions Rate (LAER), which is set on a case–by–case basis and is either the most stringent emissions limitation contained in any SIP for that category or source or the most stringent emissions limitation which is achieved for the source. NSR requirements apply to non–attainment pollutants, which are VOCs and NO_x in RI.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels and on the need to be protective of human health and the environment.

TABLE A–5 (continued)
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	Clean Air Act, Section 5 160 through 169A – Prevention of Significant Deterioration Provisions	Applicable or Relevant and Appropriate (Depending on Modelling Results)	RI has adopted SIP requirements approved and enforceable by EPA which meet the Prevention of Significant Deterioration (PSD) requirements of the CAA. These provisions require that new or modified major sources of VOCs, defined as a source which has the potential to emit 25 tons/year, install equipment to meet Best Available Control Technology (BACT). PSD requirements apply to attainment pollutants, which are SO2, CO, lead and particulates in Rhode Island.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels.
	RCRA 40 CFR 265.375 Subpart P – Thermal Treatment	Applicable	Establishes requirements for air emissions from thermal treatment units.	Remedial actions which involve thermal treatment units, as defined in 40 CFR 265.370, will meet these standards.
	RCRA 40 CFR 264.1030 – 264.1036 Subpart AA – Air Emission Standards for Process Vents	Applicable	Establishes standards for air emissions from process vents associated with distillation, fractionation, thin film evaporation, column extraction or air steam stripping operations that treat RCRA substances and have total organic concentrations of 10 ppm or greater.	If these technologies are utilized and the threshold organic concentration is met, air emissions will comply with the standards.
	RCRA 40 CFR 264.1050 – 264.1065 Subpart BB – Air Emission Standards for Equipment Leaks	Applicable	Establishes standards for air emissions for equipment that contains or contacts RCRA wastes with organic concentrations of at least 10% by weight.	If such concentrated wastes are treated, the equipment used will meet these standards.
	EPA Technical Guidance Document: Control of Air Emissions from Superfund Air Strippers at Superfund Ground Water Sites (OSWER Directive 9355.0.28)	To Be Considered	Guidance regarding the control of air emissions from air strippers used at Superfund sites for ground water treatment. Distinguishes between attainment and non–attainment areas for ozone.	These guidelines will be considered if air stripping is used as a ground water treatment alternative.

TABLE A–5 (continued)
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	RCRA 40 CFR 264 Proposed Subpart CC Organics Air Emission Standards for Tanks, Surface Impoundments, and Containers (56 FR 33490, 7/22/91)	To Be Considered	Proposed standards for air emissions from tanks, surface impoundments, and containers with VOC concentrations equal to or greater than 500 ppm.	Proposed standards will be considerd for remedial alternatives which involve the storage or treatment of hazardous wastes in tanks, surface impoundments, or containers if threshold VOC concentrations are met.
Treatment	RCRA 40 CFR 261 Identification and Listing of Hazardous Wastes	Applicable	Defines those solid wastes which are subject to regulation as hazardous wastes under 40 CFR Parts 262–265.	Wastes generated during implementation of remedial actions will be evaluated to determine if they are listed or characteristic hazardous waste.
	RCRA (40 CFR 264) Subtitle C Requirements:	Relevant and Appropriate	Outlines specifications and standards for design, operation, closure and monitoring of performance for hazardous waste storage, treatment and disposal facilities.	Substantive RCRA requirements will be met and adhered to on–site if appropriate, based on the specific remedial action.
	• 40 CFR 264.10–264.18 Subpart B – General Facility Standards	Relevant and Appropriate	General requirements regarding waste analysis, security, training, inspections, and location applicable to a facility which stores, treats or disposes of hazardous wastes (a TSDF facility).	This regulation may be applicable to remedial actions which address a waste which is a listed or characteristic waste under RCRA and which constitute current treatment, storage, or disposal as certified by RCRA.
	• 40 CFR 264.30–264.37 Subpart C – Preparedness and Prevention	Relevant and Appropriate	Requirements applicable to the design and operation, equipment, and communications associated with a TSDF facility, and to arrangements with local response departments.	This regulation may be applicable to remedial actions which address a waste which is a listed or characteristic waste under RCRA and which constitute current treatment, storage, or disposal as certified by RCRA.
	• 40 CFR 264.50–264.56 Subpart D – Contingency Plan and Emergency Procedures	Relevant and Appropriate	Emergency planning procedures applicable to a TSDF facility.	This regulation may be applicable to remedial actions which address a waste which is a listed or characteristic waste under RCRA and which constitute current treatment, storage, or disposal

TABLE A–5 (continued)
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Treatment (cont.)	• RCRA 40 CFR 265.400 – 265.406 Subpart Q – Chemical, Physical, and Biological Treatment	Applicable	General operating, waste analysis and trial test, inspection and closure requirements for facilities which treat hazardous waste by chemical, physical or biological methods in other than tanks, surface impoundments and land treatment facilities.	Remedial alternatives which utilize chemical, physical and biological treatment methods as described to treat hazardous wastes will meet these requirements.
	• RCRA 40 CFR 264.600 – 264.603 Subpart X – Miscellaneous Units	Applicable	Defines performance standards, monitoring and post–closure requirements for miscellaneous units, as defined in 40 CFR 264.10.	Remedial alternatives which utilize miscellaneous units to treat hazardous wastes will meet these requirements.

TABLE A-6
STATE ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Drainage/ Discharge	RI Water Pollution Control Act			
	° RI Water Quality Regulations for Water Pollution Control (RIGL 46-12, et seq.) RI Water Quality Standards	Applicable	Establishes general requirements and effluent limits for discharge to area waters.	In compliance with these regulations, RIPDES requirements pertaining to storm water discharges or treatment system discharges would be met.
	° Regulations for the RI Pollutant Discharge Elimination System (RIPDES) (RIGL 46-12, et seq.)	Applicable	Permits contain applicable effluent (i.e. technology - based and/or water quality - based), monitoring requirements, and standards and special conditions for discharges, including storm water discharges from land disposal facilities which have received industrial waste.	Storm water discharge improvements or ground water treatment systems would be designed to provide compliance with these regulations and drainage/discharge would be monitored in compliance with these regulations.
	• Rhode Island Pretreatment Regulations	Applicable	Covers pollutants in wastewaters which can have detrimental effects on POTW processes. Sets specified limitations, pretreatment and monitoring requirements for discharges to POTWs based on federal regulations.	Remedial actions which include discharge to a POTW will meet all required discharge limitations.
Capping/ Monitoring	RI Refuse Disposal Law Rules and Regulations for Solid Waste Management Facilities	Relevant and Appropriate	Rules and regulations intended to minimize environmental hazards associated with the operation of solid waste transfer, resource recovery, and disposal facilities.	Closure design criteria and ground water monitoring requirements may be relevant and apppropriate if a RCRA hybrid cap is considered.
	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.) Hazardous Waste Management Rules and Regulations	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage and disposal.	Substantive requirements applicable to closure will be met and adhered to on-site.

TABLE A–6 (continued)
STATE ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Capping/ Monitoring (cont.)	• Section 7	Relevant and Appropriate	Restricts location, design, construction, and operation of landfills from endangering ground water, wetlands or floodplains.	Remedial actions will be designed so as to prevent contamination of ground water, wetlands, or floodplains.
	• Section 8	Relevant and Appropriate	Outlines requirements for ground water protection, general waste analysis, security procedures, inspections and safety.	Remedial actions will comply with substantive portions of this section applicable to landfill closure.
	• Section 9	Relevant and Appropriate	Outlines operational requirements for treatment, storage and disposal facilities.	Remedial actions, including ground water monitoring, will comply with substantive portions of this section applicable to landfill closure.
	• Section 10	Relevant and Appropriate	Outlines design and operations requirements for land disposal facilities, including landfills.	Remedial actions will meet all non–location specific requirements of this section applicable to landfill closure.
	Rules and Regulations for Ground Water Quality	Applicable	Rules and regulations intended to protect and restore the quality of the State's ground water. Includes ground water program monitoring requirements and monitoring well construction and abandonment standards.	Ground water monitoring programs and well construction/abandonment methodologies will comply with these regulations.

TABLE A–6 (continued)
STATE ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC – DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air	RI Clean Air Act (RIGL, Title 23, Chapter 23) General Air Quality and Air Emissions Requirements • RI Air Pollution Control Regulations, RI Dept. of Health, Div. of Air Pollution Control, effective 8/2/67, most recently amended 5/20/91			
	– Regulation No. 1 – Visible Emissions	Applicable	No air contaminant emissions will be allowed for more than 3 minutes in any one hour which are greater than or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulation.
	– Regulation No. 5 – Fugitive Dust	Applicable	Requires that reasonable precaution be taken to prevent particulate matter from becoming airborne.	On–site remedial actions will use good industrial practices to prevent particulate matter from becoming airborne.
	– Regulation No. 7 – Emissions Detrimental to Person or Property	Applicable	Prohibits emissions of contaminants which may be injurious to human, plant or animal life or cause damage to property or which reasonably interferes with the enjoyment of life and property.	All emissions will meet this requirement or gas treatment will be required.
	– Regulation No. 9 – Approval to Construct, Install, Modify or Operate	Applicable	Establishes guidelines for the construction, installation, modification or operation of potential air emission units. Establishes permissible emission rates for some contaminants.	Technologies involving construction, installation, modification or operation of air emission units will meet these requirements.
	– Regulation No. 15 – Control of Organic Solvent Emissions	Applicable	Limits the amount of organic solvents emitted to the atmosphere.	If emissions exceed limits in this regulation, emission controls will be designed and implemented to meet these requirements.

TABLE A-6 (continued)
STATE ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 09 - ALLEN HARBOR LANDFILL
NCBC - DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	– Regulation No. 17 – Odors	Applicable	Prohibits the release of objectionable odors across property lines.	No remedial action or air emissions will emit objectionable odors beyond the facility boundary, as practicable.
	– Regulation No. 22 – Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels or acceptable ambient levels with LAER, as set in the regulation.	If air emissions contain regulated substances, air emissions control equipment will be used as necessary to meet these standards.
Treatment	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)			
	Hazardous Waste Management Rules and Regulations	Applicable	Rules and regulations for hazardous waste generation, transportation, treatment, storage and disposal.	Substantive requirements applicable to hazardous waste treatment will be met and adhered to on-site.
	• Section 8	Applicable	Outlines operational requirements for all hazardous waste treatment facilities.	Any hazardous waste treatment actions will comply with the substantive requirements of this section which apply to treatment technologies.
	• Section 9	Applicable	Outlines requirements for general waste analysis, security procedures, inspections and safety.	All remedial actions involving treatment of hazardous wastes will comply with the applicable portions of this section.
	• Section 13	Applicable	Outlines design and operational requirements for miscellaneous units, as defined in 40 CFR 260.10.	Remedial alternatives which utilize miscellaneous units to treat hazardous wastes will meet the applicable requirements of this section.

APPENDIX B

CALCULATION OF PRELIMINARY RISK-BASED REMEDIATION GOALS

As described in the National Contingency Plan [40 CFR 300.430(e)(2)(i)(A)(2)], "The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available...". U.S. EPA Region I's exposures assessment methodology specifies the use of the "reasonable maximum exposure (RME) scenario" in estimating the risks associated with a given site. In the Phase II RI Report, the risk assessment presented risk estimates based on the maximum detected constituent concentration (which was referred to as "worst-case"), and based on the geometric mean of constituent concentrations (which was referred to as "most probable"). Since use of the maximum detected concentration coincides with U.S. EPA Region I's definition of the RME scenario, the calculated risks for this scenario were evaluated to determine if the 10^{-6} point of departure risk level is exceeded for any individual constituents. A similar evaluation was also conducted to identify constituents with noncarcinogenic hazard quotients above unity in the Phase II RI Risk Assessment.

<u>Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim</u> (USEPA, 1991a) provides additional guidance on the development of risk-based preliminary remediation goals (PRGs). One of the initial steps in development of PRGs is the identification of the most appropriate future land use for the site so that the appropriate exposure pathways, parameters and equations can be used to calculate PRGs. At Site 09, based on the Comprehensive Base Reuse Plan, the most appropriate future land use is as a recreational/conservation area. Therefore, exposures to surface soils, the only exposure pathway evaluated under the Human Health Risk Assessment for the future recreational exposure scenario, will guide the development of PRGs. Exposures to ground water are not anticipated, based on the site's proximity to Allen Harbor and the potential brackishness of the ground water. Based on the sharp topographic drop to the shoreline of the site and the gravelly nature of the shoreline area, recreational exposure to shoreline sediments is not anticipated to pose a major exposure pathway.

As summarized in Table B-1, those soil constituents which contributed an individual RME cancer risk of greater than 1 x 10^{-6} to the overall cancer risk estimate, or an individual RME hazard quotient of greater than one to the total hazard index for noncarcinogenic risks, were identified and then evaluated to determine if there were any for which an ARAR/TBC was not available. For those constituents without an associated ARAR/TBC, a risk-based preliminary remediation goal (PRG) was calculated, based on a future recreational use scenario. As shown in Table B-2, the calculations for soil incorporate recreational exposures as a child/youth (ages 2 to 18 years). Under this scenario, exposure is assumed to occur through incidental ingestion of and dermal contact with soil. The exposure parameters for the soil calculations are taken directly from the risk assessment portion of the Phase II RI.

Table B-1
Site 09 -- Allen Harbor Landfill
Constituents Considered for the Development of Risk-Based
Preliminary Remediation Goals [a]

Constituent	Scenario	Medium	Cancer Risk or Hazard Quotient Elevated?	ARAR Available?	Selected for Development of Risk-Based PRGs?
Arsenic	Recreational	Soil	CR_{RME}	NA	Yes
Beryllium	Recreational	Soil	CR_{RME}	NA	Yes
Benzo(a)anthracene	Recreational	Soil	CR_{RME}	NA	Yes
Benzo(a)pyrene	Recreational	Soil	CR_{RME}	NA	Yes
Benzo(b/k)flouranthene	Recreational	Soil	CR	NA	Y s
Chrysene	Recreational	Soil	CR_{RME}	NA	Y s
Dibenzo(a,h)anthracene	Recreational	Soil	CR_{RME}	NA	Yes
Indeno(1,2,3-cd)pyrene	Recreational	Soil	CR_{RME}	NA	Yes
TCDD, 2,3,7,8-	Recreational	Soil	CR	NA	Yes
Aroclor-1260	Recreational	Soil	CR_{RME}	Yes	No

NA = Not applicable
[a] i.e., Constituents associated with individual cancer risks above 1E-06 or hazard quotients above 1 as estimated under the recreational exposure scenario for soil

Table B–2
Site 09 – Allen Harbor Landfill
Cancer–Risk–Based Preliminary Remediation Goals (PRGs) for Constituents in Soil
Assuming Future Recreational Land Use by Children/Youths Aged 2 to 18 Years

Constituent	Oral Slope Factor (SF) $(mg/kd*d)^{-1}$	Oral Relative Absorption Factor (RAF) (––)	Dermal Relative Absorption Factor (RAF) (––)	Soil PRG (a) (mg/kg)
Arsenic	1.8E+00	1	NA	3.3E+00 (c)
Beryllium	4.3E+00	1	NA	1.4E+00
Benzo(a)anthracene (b)	7.3E+00	1	NA	8.2E–01 (d)
Benzo(a)pyrene	7.3E+00	1	NA	8.2E–01 (d)
Benzo(b)fluoranthene (b)	7.3E+00	1	NA	8.2E–01 (d)
Benzo(k)fluoranthene (b)	7.3E+00	1	NA	8.2E–01 (d)
Chrysene (b)	7.3E+00	1	NA	8.2E–01 (d)
Dibenzo(a,h)anthracene (b)	7.3E+00	1	NA	8.2E–01 (d)
Indeno(1,2,3–cd)pyrene (b)	7.3E+00	1	NA	8.2E–01 (d)
TCDD, 2,3,7,8– equivalents	1.5E+05	1	0.04	3.6E–05 (e)

(a) Based on USEPA (1991) guidance and Phase II Human Health Risk Assessment
(b) Carcinogenic PAHs assigned slope factor for benzo(a) pyrene per EPA Region I guidance
(c) PRG is less than the upper range of 8.1 mg/kg for background levels of arsenic around the NCBC facility
(d) Corresponds to a PRG for total carcinogenic PAHs in soil of ~6 mg/kg
(e) PRG is greater than the maximum detected concentration of 2,3,7,8– TCDD equivalents

$$PRG = [TR * AT * BW] / [SF * CF * (IR_s * RAF_o + CR_s * RAF_d) * EF * ED]$$

Where:

TR = Target cancer risk:	1E–06	––
AT = Averaging time:	25550	d
BW = Body weight:	33.9	kg
SF = Oral cancer slope factor:	CS	Chemical–specific
CF = Conversion factor:	1E–06	kg/mg
IR_s = Soil ingestion rate:	125	mg/d
RAF_o = Oral Relative absorption factor:	CS	Chemical–specific
CR_s = Soil contact rate:	355	mg/d
RAF_d = Dermal Relative absorption factor:	CS	Chemical–specific
EF = Exposure frequency:	72	d/yr
ED = Exposure duration:	16	yr

APPENDIX C

EVALUATION OF LEACHING POTENTIAL BASED ON APPLICATION OF LEACHING MODEL

To evaluate the potential for surface and subsurface soil contaminants to leach into the ground water, an infiltration/leaching model was used. USEPA's document entitled Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples (EPA/540/2-89/057, October 1989) presents various methods which have been used to derive soil cleanup levels based on potential threats to ground water quality.

The Summers model and the "unnamed" model, as described in this USEPA document, were evaluated in terms of applicability to site conditions at Site 09 - Allen Harbor Landfill. Both of these three-dimensional models assume that a percentage of rainfall will infiltrate and desorb contaminants from the soil based on equilibrium soil:water partitioning. It is assumed that this contaminated infiltration will mix completely with ground water below the site, resulting in an equilibrium ground water concentration with all contaminants from the infiltration in the final mixture. The Summers model is applicable to a large spill area and is based on a mass balance approach which is applied to the entire area and affected soil volume of the spill. Therefore, it involves a mass balance of the total volume and contaminant concentration of infiltration over the entire area of the site, the total volume and contaminant concentration of ground water flowing into the site area, and the total volume and contaminant concentration of ground water exiting the site.

The unnamed model is a variation of the Summers model in which the mass balance approach is applied to a column of the site, of unit area and of depth equal to the saturated portion of the aquifer. Since subsurface contamination at Site 09 is heterogeneous, characterized by small areas of elevated contamination, rather than consistently contaminated throughout the areal extent of the site, application of the unnamed model was determined to be more appropriate. The unnamed model also provides for the separate estimation of critical saturated and unsaturated soil contaminant levels

Data Requirements

- Volumetric flow rate of recharge flowing downward through a unit area (based on the infiltration rate of precipitation) (cf/day)
- Volumetric flow rate of ground water in saturated zone in water column through unit width (cf/day)
- Concentration of contaminant in ground water recharge (μg/l)
- Hydraulic conductivity (ft/day)
- Hydraulic gradient (ft/ft)
- Concentration of contaminant adsorbed to the soil in the unsaturated zone (μg/kg)
- Concentration of contaminant in ground water in the saturated zone (μg/l)
- Total organic carbon concentration (mg/mg)

Method Description

In the unnamed model, soil cleanup levels (or maximum allowable soil contaminant levels) are calculated for saturated and unsaturated soils assuming equilibrium between dissolved and adsorbed phases for each contaminant using the following relationship:

$$S_{sat} = (K_d)(C_{sat}) \tag{1}$$

where: S_{sat} = concentration of contaminant adsorbed to the soil in the saturated zone (μg/kg)
K_d = distribution coefficient
C_{sat} = concentration of contaminant in ground water in saturated zone (μg/l)

The K_d is calculated as follows:

$$K_d = (0.63)(F_{oc})(K_{ow}) \tag{2}$$

where: 0.63 = Adjustment factor
F_{oc} = total organic carbon concentration in soil (mg/mg)
K_{ow} = octanol-water partition coefficient

In calculating K_d, it is assumed that the maximum desired contaminant concentration for ground water is equal to an established health-based criteria (i.e., MCLs). Using equation (1), the maximum soil contaminant concentration in the saturated zone may then be calculated.

Subsequent calculations to derive unsaturated soil maximum contaminant concentrations include the assumption that dissolved contamination in ground water recharge reaches equilibrium with the adsorbed phase on unsaturated soils, and that such recharge is fully diluted into the entire water column upon reaching the water table. Thus the maximum unsaturated soil contaminant level is established using equation (1) and a dilution equation for calculating C_{sat}, the contaminant concentration in the ground water in the saturated zone which is based on the mass-balance approach, as indicated in Figure C-1.

$$C_{sat} = (C_{unsat})(e)/(e+Q) \tag{3}$$

where:

where:	C_{unsat}	=	contaminant concentration of ground water in recharge (μg/l)
	e	=	volumetric flow rate of recharge flowing downward through a unit area (cf/day)
	Q	=	volumetric flow rate of ground water in the saturated zone throughout the unit (cf/day)

The equilibrium assumption:

$$S_{unsat} = (K_d)(C_{unsat}) \tag{4}$$

and equation (1) combined with equation (3) yields the following relationship. The resultant equation is used to calculate the maximum contaminant concentration for soils in the unsaturated zone.

$$(S_{sat})/(K_d) = (S_{unsat})/(K_d)(e)/(e+Q)$$

and

$$S_{unsat} = (S_{sat})(e + Q)/e \tag{5}$$

where: S_{unsat} = concentration of contaminant adsorbed to the soil in the unsaturated zone (μg/kg)

and the ground water volumetric flow rate through the saturated zone (Q) is estimated from Darcy's Law:

$$Q = (K)\ (i)\ (A) \tag{6}$$

where: K = hydraulic conductivity (ft/day)
i = hydraulic flow gradient (ft/ft)
A = area of flow (unit width x saturated thickness of aquifer) (ft^2)

Site-Specific Application

At Site 09 - Allen Harbor Landfill, three Phase II RI soil samples were analyzed for total organic carbon. Detected levels were 13,600 mg/kg, 13,400 mg/kg and 9,450 mg/kg, with an average level of 12,000 mg/kg or 0.012 mg/mg. Using this value and published octanol-water partition coefficient values, the maximum saturated soil contaminant level was calculated for the Contaminants of Concern identified in the Phase II RI for which an MCL was available. The contaminants, octanol-water partition coefficients (K_{ow}) values used, calculated K_d values, assumed maximum ground water concentrations in the saturated zone (C_{sat} = MCL) and maximum saturated soil contaminant levels (S_{sat}) are presented in the first 4 columns of Table C-1. Also noted in columns 5 and 6 are the maximum detected concentration in the saturated zone and the location of the maximum detected concentration for each contaminant. The depth of the saturated zone was determined by the depth to ground water for monitoring wells or the depth at which wet soils were first observed for soil borings, as reported in the Phase II RI. Also noted in Note (1) beneath the table are the other locations at which contaminants were detected in saturated soil samples at levels exceeding the calculated maximum allowable level.

To calculate the maximum acceptable unsaturated soil contaminant levels, the volumetric flow rate of ground water in the saturated zone through the unit area (Q) was calculated. The average linear velocity for the site was estimated to be 0.495 ft/day by averaging the velocity values presented in Table 2-11 of the Phase II RI. The average saturated thickness, estimated at 8 feet, was calculated by averaging the thickness of the interval from the water table surface to the top of the silt layer as measured at the on-site monitoring wells. Therefore, for a unit width of soil,

$$\begin{aligned} Q &= (0.495 \text{ ft/day})\ (8 \text{ ft})\ (1 \text{ ft}) \\ &= 3.96 \text{ cf/d} \end{aligned}$$

To estimated e, the volumetric flow rate of recharge flowing downward through a unit area, the information provided in Section 1.3.2 of the Phase II RI regarding precipitation and infiltration was used. Based on an average annual precipitation of 42.3 inches and 36% infiltration, the annual infiltration is 1.27 ft/yr or 0.0035 ft/day. Therefore, for a unit area of surface,

$$\begin{aligned} e &= (0.0035 \text{ ft/day})\ (1 \text{ ft})\ (1 \text{ ft}) \\ &= 0.0035 \text{ cf/day} \end{aligned}$$

Then S_{unsat} can be calculated using equation (5), where:

$$\begin{aligned} S_{unsat} &= (S_{sat})\ (e + Q)/e \\ &= (S_{sat})\ (0.0035 + 3.96)/0.0035 \\ &= (S_{sat})\ (1132.4) \end{aligned}$$

The calculated S_{unsat} values are presented in column 9 of Table C-1. The maximum detected soil contaminant levels in the unsaturated zone and the location of the maximum detected concentration for each contaminant are presented in columns 10 and 11, respectively. The only contaminant detected in unsaturated soils at levels exceeding the maximum calculated allowable level was toluene in test pit sample TP-6-02-S, which was collected from beneath a drum that accidentally ruptured during test pit activities. No other unsaturated soil samples exhibited contaminants at levels exceeding the calculated maximum allowable level.

TABLE C-1

Comparsion of Soil Contaminant Levels to Modeled Soil Response Action Levels
Using the Unnamed Model (USEPA, EPA/540/2-89/057)

Column:	1	2	3	4	5	6	7	8	9	10	11
Constituent	K_{ow}	K_d	C_{sat} (ppm)	S_{sat} (ppm)	Max. Saturated Subsurface Soil Concentration Detected (ppm)	Location of Maximum Detected Level	Q (cf/d)	e (cf/d)	S_{unsat} (ppm)	Max. Unsaturated Soil Concentration Detected (ppm)	Sample Location
Benzene	135	1.02	0.005	0.00510	0.003	09-MW5-06	3.96	0.0035	5.78	1.50	TP-6-02-S
Chloroform	89.1	0.674	0.1	0.0674	--		3.96	0.0035	76.3	0.002	TP-3-06-S, TP-9-08-S
1,2-Dichloroethene(1)	30.2	0.228	0.07/0.1	0.0160/0.022	3.1	09-MW7-23	3.96	0.0035	18.1/25.8	0.014	09-MW6-08
1,1,1-Trichloroethane	295	2.23	0.2	0.446	0.004	09-MW9-08	3.96	0.0035	505	0.013	09-MW6-08
Trichloroethene	339	2.56	0.005	0.0128	0.002	09-MW5-06, 09-MW11-0	3.96	0.0035	14.5	3.8	TP-6-02-S
Tetrachloroethene	339	2.56	0.005	0.0128	--		3.96	0.0035	14.5	0.012	09-B1-01
Toluene	490	3.70	1	3.70	0.082	09-MW5-06	3.96	0.0035	4190	15000	TP-6-02-S
Ethylbenzene	1410	10.7	0.7	7.46	0.038	09-MW5-06	3.96	0.0035	8450	910	TP-6-02-S
Xylenes	1000	7.56	10	75.6	0.11	09-MW5-06	3.96	0.0035	85600	4200	TP-6-02-S
Bis(2-ethylhexyl)phthalate	2.00E+05	1510	0.006	9.06	0.76	09-B9-03	3.96	0.0035	10300	33	TP-6-02-S
Butylbenzylphthalate	6.03E+04	456	0.1	45.6	0.27	09-B9-03	3.96	0.0035	51600	13	09-MW6-08
Chrysene(2)	2.45E+05	1850	0.0002	0.370	320	09-MW5-06	3.96	0.0035	419	17	09-MW5-04
1,2-Dichlorobenzene	2400	18.1	0.6	10.9	--		3.96	0.0035	12300	63	09-B7-01
1,4-Dichlorobenzene	2460	18.6	0.075	1.40	0.11	09-MW10-09	3.96	0.0035	1590	0.18	09-B7-06
Indeno(1,2,3-cd)pyrene	4.57E+07	346000	0.0004	138	79	09-MW5-06	3.96	0.0035	156000	25	09-MW5-01
Dibenzo(a,h)anthracene(2)	9.33E+05	7060	0.0003	2.12	29	09-MW5-06	3.96	0.0035	2400	7.4	09-MW5-01
Benzo(a)anthracene(2)	4.07E+05	3080	0.0001	0.308	420	09-MW5-06	3.96	0.0035	349	69	09-B7-01
Benzo(a)pyrene(2)	9.55E+05	7220	0.0002	1.44	150	09-MW5-06	3.96	0.0035	1630	45	09-B7-01
Benzo(k)fluoranthene(2)	6.92E+06	52300	0.0002	10.5	490	09-MW5-06	3.96	0.0035	11900	110	09-B7-01
Chlordane	8.51E+05	6430	0.002	12.9	0.013	09-B3-03	3.96	0.0035	14600	0.039	09-B7-06
Endrin	3.98E+05	3010	0.002	6.02	0.097	09-MW5-06	3.96	0.0035	6820	0.026	09-SS05(Dup)
PCBs	8.13E+06	61500	0.0005	30.8	0.13	09-MW11-05	3.96	0.0035	34900	30	09-MW11-01

K_d = 0.63 x 0.012 x K_{ow} where 0.63 = adjustment factor and 0.012 = average total organic carbon concentration

C_{sat} = Maximum Contaminant Level

S_{sat} = C_{sat} x K_d

Q = Avg linear velocity * unit area

Avg linear velocity = 0.495 ft/d (from Table 2-11 of Phase II RI)

Unit Area = Avg saturated thickness to top of silt (8 ft) * unit width (1 ft) = 8 sq ft

Q = .495 x 8 = 3.96 cf/d

e = infiltration rate x unit area

Infiltration rate = 15.2 in/yr = 0.0035 ft/d (= recharge at 36% of average annual 42.3 in precipitation)

Unit area = 1 ft by 1 ft = 1 sq ft

e = 0.0035 x 1 = 0.0035 cf/d

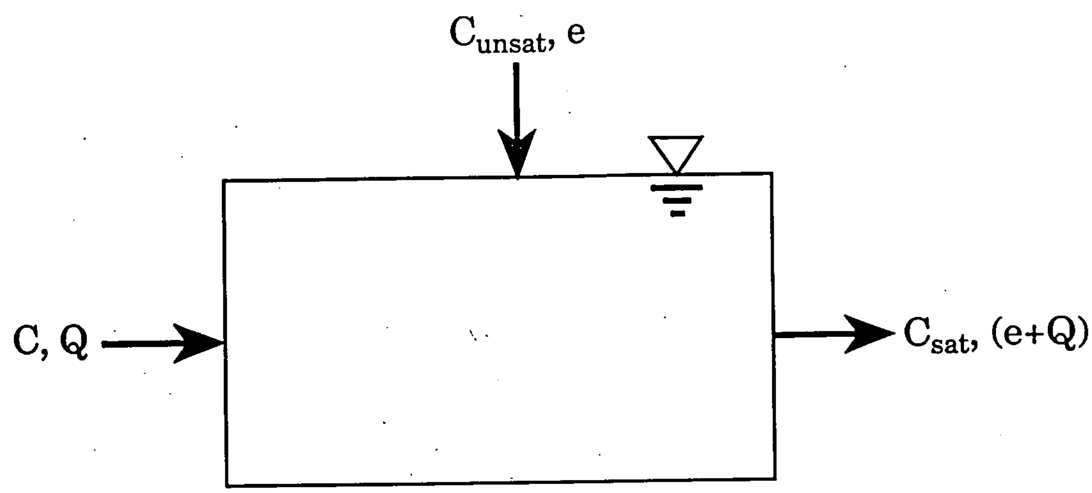
S_{unsat} = S_{sat} x (e+Q)/e

NOTES:

(1) - Separate cleanup levels are calculated using MCL values for both the cis and trans- isomers of 1,2-dichloroethene

(2) - The S_{sat} levels for chrysene and benzo(a)anthracene were also exceeded by the following saturated soil samples: 09-B3-03, 09-MW8-06, 09-MW9-08, 09-MW10-09 AND 09-MW11-05

FIGURE C-1
MASS BALANCE DERIVATION OF THE INFILTRATION EQUATION



$$(C_{unsat})\,(e) + (C)\,(Q) = (C_{sat})\,(e + Q)$$

$$C_{sat} = [(C_{unsat})\,(e) + (C)\,(Q)] \,/\, (e + Q)$$

Since C = 0, then:

$$C_{sat} = (C_{unsat})\,(e) \,/\, (e + Q)$$

C_{sat}	=	concentration of contaminant in ground water in saturated zone (µg/l)
C	=	initial concentration of contaminant in ground water (assumed zero)
C_{unsat}	=	contaminant concentration of ground water in recharge (µg/l)
e	=	volumetric flow rate of infiltration (cf/day)
Q	=	volumetric flow rate of ground water in the saturated zone throughout the unit (cf/day)

APPENDIX D

TECHNOLOGY AND PROCESS OPTION SCREENING AND REMEDIAL ALTERNATIVE DEVELOPMENT

Based on the general response actions developed for Site 09, remedial technologies which could potentially meet the remedial action objectives and cleanup criteria are identified and screened. This process is a two-step process in which technologies are initially screened on the basis of technical implementability. For the technologies which pass the initial screening, the process options associated with each technology are screened based on effectiveness, implementability and cost. Representative process options are then chosen based on this screening for inclusion in the comprehensive remedial alternatives developed for the site.

Technology Screening

The intent of the technology screening is to reduce the universe of potentially applicable technology types and process options based on technical implementability. Two factors which may be considered in the evaluation of the technical implementability of a technology are the type of contaminants present at a site and site-specific conditions which may limit the implementability of a technology. Examples of the application of these factors include the screening of a technology because it treats volatile organics, when inorganics are the contaminants of concern, or the screening of a technology which cannot be applied to a site due to site-specific subsurface conditions. The technologies or technology process options which do not pass the screening process on the basis of technical implementability are not retained for further consideration.

A combined technology screening was performed for all of the sites addressed within the Initial Screening of Alternatives Report. The technology screening presented herein revisits the technology screening, considering the results of the Phase II RI. The Site 09 technology screening is conducted for soil/waste in Table 3-9 of the report, for ground water in Table 3-10 and for sediment in Table 3-11.

The technology screening tables each include brief descriptions of the individual technologies or process options. More detailed descriptions of the technologies are provided in the text which follows this introduction.

The technology screening tables also include comments on the general applicability of the technologies and limiting characteristics which may prevent their application at Site 09. The technology or process option title block is shaded gray only for those technologies which have been screened from further analysis.

For Site 09 soil/waste, the potential remedial technologies presented in Table 3-9 were identified based on expectations of Superfund regarding remediation of landfill sites (se Section 3.1) as well as on the basis of the determination that RCRA closure requirements are relevant and appropriate to the closure of the landfill. The technologies which were identified include no action, site use restrictions, surface controls and capping. None of the identified technologies were screened from further consideration based on technical implementability.

The potential remedial technologies identified for ground water at Site 09 include no action, ground water monitoring, ground water use restrictions, capping, vertical barrier, extraction, off-site treatment, biological/physical/chemical treatment, inorganic treatment, in-situ treatment, and discharge. Two technologies, off-site treatment and in-situ treatment were screened from further consideration. Off-site treatment was screened based on difficulties associated with the technical implementability of off-site ground water treatment at a POTW or at a RCRA facility.. The ground water contaminants which exceed water quality standards include both organics and inorganics. The chlorinated organics are not treatable by standard POTW treatment processes. The lack of a nearby RCRA treatment facility and the typically large volumes of water generated on an on-going basis by a ground water extraction system eliminate the feasibility of off-site treatment at a RCRA facility. In situ treatment was screened mainly due to the difficulty of achieving consistent in situ treatment within the heterogeneous subsurface environment of a landfill.

Ground water process options screened from further consideration include provision of an alternative water supply and well point and interceptor trench extraction systems. Due to the lack of potable ground water receptors, provision of an alternate water supply is not technically implementable. Due to the depth of the water table, well point and interceptor trenches would not be effective means of extracting ground water.

For sediment at Site 09, identified remedial technologies mirrored those developed for soil/waste, although the capping process option was limited to stone. Placement of a stone revetment over the contaminated sediments, especially along the shoreline area, was the only capping technology identified which would be technically implementable, meeting the remedial response objectives and resisting the environmental forces possible in a shoreline area.

Process Option Screening

Upon identification of those technologies which are technically implementable, the process options are further evaluated to allow the selection of representative process option(s) for each technology type. In the process option screening, the process options are evaluated on the basis of effectiveness, implementability, and cost. Factors considered in the effectiveness evaluation include the effectiveness of the process in handling the estimated areas or volumes of media, its ability in meeting remediation goals, potential impacts to human health and the environment during construction and implementation, and how proven and reliable the process is. Both technical and administrative feasibility are considered in the implementability evaluation, while relative capital and O&M costs are broadly compared in the cost evaluations.

The process option evaluation for soil/waste is presented in Table 3-12 of the report, the evaluation for ground water is presented in Table 3-13 and the evaluation for sediment is presented in Table 3-14. The selected representative process options are indicated with an asterisk in these tables.

Due to the limited number of process options evaluated for soil/waste, all of the process options were retained for further consideration, as indicated in Table 3-12.

For ground water, one of the process options for creating a vertical barrier around the site was selected for further consideration. Sheet piling was chosen over a slurry wall based on the technical difficulty of constructing a slurry wall along the shoreline portion of the landfill as well as the proven use of sheet piling marine-type applications. Of the numerous organic treatment process options considered, air stripping and UV oxidation were selected as the treatment process options which would be expected to be easily implemented, successful in treating the organic contaminants within the ground water and cost-effective. Based on the evaluation of ground water contaminants with respect to water quality criteria presented in Table 3-2, chlorinated volatile organics were the major organic contaminants detected at levels exceeding water quality criteria. The selected process options offer effective treatment of chlorinated organics while also being easy to implement and offering significant reductions in the toxicity of the contamination. Similarly, for inorganic treatment, precipitation and membrane microfiltration were selected as representative process options to be used for remedial alternative development. Precipitation is a well-demonstrated technology which is capable of treating a variety of inorganic constituents. Normal filtration processes may not be successful in physically separating the inorganics from the ground water, since inorganic analyses conducted on filtered and unfiltered samples collected using the low flow sampling methodology (which reduced the siltiness of the samples) indicated that the inorganics are probably dissolved rather than suspended (filtered and unfiltered results were comparable). However, microfiltration utilizes a filter with smaller openings than that used in the analysis of filtered ground water samples, and it may be successful in achieving discharge requirements for inorganics. Ion exchange is a commonly used inorganic treatment technology but the resin must be tailored to the contaminants requiring treatment. Electrochemical treatment is not as well proven as the other process options in treating contaminated ground water although it has been proven effective in the precipitation of certain inorganic species. It is a relatively complicated process, requiring a significant amount of operator attention. Therefore, precipitation and membrane microfiltration were selected as representative inorganic treatment process options. For ground water discharge, discharge to surface water ground water was selected as the representative discharge option. Discharge to ground water would be difficult on-site due to the presence of waste materials over the majority of the site, the presence of silts beneath the wastes which would not readily accept ground water recharge and the elevated inorganics levels which could cause clogging of a recharge system. Discharging to a POTW was not considered to be as administratively or economically feasible as discharge to surface water.

As with the soil/waste process options, based on the limited number of process options evaluated for sediment, all of the process options were retained for further consideration, as indicated in Table 3-14.

TECHNOLOGY AND PROCESS OPTION SCREENING

SOIL/WASTE REMEDIAL TECHNOLOGIES

Site Use Restrictions

Site use restrictions are intended to prevent or reduce exposure to on-site contamination. They include actions such as fencing, signage, and restrictive covenants on the property deed to prevent development of the site or use of the ground water of the site. Site use restrictions may also be imposed to reduce required maintenance and to protect the integrity of a remedial alternative such as a cap. Conditions in the area of the site should be evaluated in the five-year reviews to assess the continuing or future need for site use restrictions. The two types of access restrictions most used at municipal landfill sites include deed restrictions and fencing.

Deed Restrictions

Deed restrictions are intended to prevent or limit site use and development. Restrictive covenants, written into the landfill property deed, notify any potential purchaser of the landfill property that the land was used for waste disposal and that the land use must be restricted in order to ensure the integrity of any waste containment systems, if they exist. Based on the closure of the NCBC facility, deed restrictions could be incorporated into property transfer documents, as required. The effectiveness of deed restrictions depends on state and local laws, continued enforcement, and maintenance.

Fencing

Fencing is used to physically limit access to the landfill site. The most common type of fence used to limit access is a chain-link fence about eight feet high. Signs may be posted to make clear to potential trespassers that there may be a health threat associated with direct exposure to the site. Fencing may also help reduce the required maintenance and protect the integrity of a containment system such as a landfill cap.

Surface Controls

Surface control technologies are designed to control and direct site runoff and to prevent off-site surface water from running onto the site. Surface controls to divert run-on and minimize infiltration at landfill sites often are implemented in conjunction with site closure. Such controls are almost always employed in concert with other technologies such as installation of a landfill cap. Surface controls most commonly used at landfill sites are grading and revegetation.

Grading

Grading modifies topography in order to promote positive drainage and control the flow of surface water. Grading can also control erosion and manage surface water infiltration, run-on, and runoff. In conjunction with a landfill, proper grading will channel uncontaminated surface water around the landfill, thereby minimizing surface infiltration. Grading is often used in conjunction with capping and revegetation and can have a considerable impact in reducing leachate generation associated with infiltration.

Revegetation

Revegetation is a method used to stabilize surface soils of a site and promote evapotranspiration. Revegetation decreases erosion of the soil by wind and water, reduces sedimentation in stormwater runoff, and contributes to the development of a naturally stable surface. Revegetation can also improve the aesthetics or ecological value of the site. A systematic revegetation plan includes selection of suitable plant species, seedbed preparation, seeding/planting, mulching and/or chemical stabilization, fertilization, and maintenance. Revegetation is used most in combination with containment technologies such as a landfill cap. In such an instance, the root penetration of the revegetation species must be considered to ensure the integrity of any barrier layer within the cap will not be compromised.

Capping

Capping is a process used to cover contaminated materials to prevent their contact with the land surface, infiltrating precipitation, and/or ground water. Capping is applicable whenever contaminated materials are to be buried or left in place at a site. In general, capping is performed when extensive subsurface contamination at a site precludes excavation and removal of wastes because of potential hazards and/or unrealistic costs.

Capping is often performed together with ground water extraction or other containment technologies to prevent, or significantly reduce further plume development, thus reducing the time needed to complete ground water cleanup operations.

There are a variety of designs and capping materials available. ARARs can drive the design criteria of a cap. The performance standards of 40 CFR 264.310 address RCRA landfill closure requirements (Subtitle C caps), while 40 CFR 258 presents standards for municipal solid waste landfill caps (Subtitle D caps). The selection of capping materials and a cap design is influenced by specific factors such as local availability, costs of cover materials, desired function of cover materials, the nature of the contaminated materials, local climate and hydrogeology, and projected future use of the site in question.

As discussed in Appendix A, RCRA closure requirements are considered to be relative and appropriate to the closure of Allen Harbor Landfill. Therefore, Subtitle C RCRA-based cap designs are considered rather than Subtitle D municipal landfill cap designs. Two RCRA cap designs, a RCRA hybrid cap and a RCRA subtitle C landfill cap, are discussed briefly below. Also considered is a native soil cap, which would allow for revegetation of the site with deep-rooted species similar to those currently existing. Implementation of a non-RCRA cap would require a waiver of ARARs.

The main disadvantages of capping are the need for long-term maintenance and uncertain design life. Another disadvantage to capping is the high cost of proper soil and drainage materials in certain areas of the country.

Native Soil Cap

Native soil caps are used when the primary objective is to control erosion and prevent direct contact with underlying materials. A relatively thick native soil cap can support deep-rooted vegetation with no compromise in the effectiveness of the cap.

RCRA Subtitle C Hybrid Cap

Use of a RCRA Subtitle C hybrid closure approach is appropriate when RCRA closure requirements are relevant and appropriate but not applicable. Hybrid closure is used when residual contamination poses a direct contact threat, but does not pose a ground water threat. Covers, which may be permeable, are used to address the direct contact threat while limited long-term management, including site and cover maintenance and minimal ground water monitoring, and institutional controls are used as necessary to ensure the long-term effectiveness of the cap.

RCRA Subtitle C Landfill Cap

Use of a RCRA Subtitle C landfill closure approach would exceed relevant and appropriate RCRA closure requirements. A RCRA Subtitle C landfill cap must provide long-term minimization of migration of liquids; function with minimum maintenance; promote drainage and minimize erosion; accommodate settling and subsidence; and have a permeability less than or equal to any bottom liner system or natural subsoils present. Typically, a RCRA cap is multi-layer and designed with a double barrier. A typical design could consist of a vegetative layer, a drainage layer, a combined soil and geosynthetic barrier layer and a bedding layer.

GROUND WATER/LEACHATE REMEDIAL TECHNOLOGIES

Institutional Control

Institutional controls are intended to minimize exposures to contaminated ground water. They include actions such as ground water monitoring, ground water use restrictions and provision of alternate water supplies. If a five-year review is required for a remedial action involving institutional controls, site conditions such as ground water monitoring results or changes in ground water usage should be reviewed to determine the need for continuing or future site use restrictions.

Ground Water Monitoring

Ground water monitoring provides a means to assess changes in ground water quality and contaminant migration patterns. Ground water monitoring may be performed as a part of a five-year review of a site.

Ground Water Use Restrictions

Ground water use restrictions are intended to prevent or reduce exposure to ground water contamination. The use of ground water below or adjacent to the site is usually restricted. Ground water use restrictions may encompass potable use as well as non-potable use of the ground water. At Site 09, potable use would not be anticipated due to the brackishness of the ground water. However, non-potable use could be conceivable in association with potential future recreational site use.

Alternate Water Supply

Alternate water supply represents another type of institutional control in restricting ground water usage. Basically, ground water that is contaminated is no longer utilized as a potable water source, and an alternate source is provided. Since ground water is not used for potable water supply in the vicinity of Site 09, this process option is screened from further consideration.

Vertical Barriers

Vertical barriers are low permeability cut-off walls or diversions installed below ground to contain, capture, or redirect ground water flow in the vicinity of a site. Vertical barriers may improve the overall effectiveness of a containment system. The most commonly used vertical barriers are slurry walls, particularly soil-bentonite slurry walls. Less common are cement-bentonite or concrete slurry walls, grouted barriers, and sheet piling cut-offs. Vertical barriers are most effective when they can "key" into natural subsurface impermeable layers.

Slurry Wall

Slurry walls are used as vertical barriers to reduce the horizontal permeability of the soil. These walls can be excavated a limited distance into rock material (i.e. keyed into bedrock). Shallow slurry walls keyed into impermeable clays offer a cost-effective means of reducing the ground water flow in unconsolidated earth materials. However, it is difficult to completely intercept ground water using just slurry walls; therefore, they are usually implemented with other containment technologies, such as a ground water extraction system and a landfill cap. Construction of a slurry wall along the seaward perimeter of Site 09 could be technically difficult to implement, based on the required excavation of a trench and the presence of wastes right up to the shoreline. Also due to the presence of subsurface wastes along the shoreline, a cement/bentonite slurry wall would be required since the presence of wastes in the excavated trench material would prohibit the use of the excavated material in the construction of a soil/bentonite wall. The cost of materials to construct a cement/bentonite slurry wall can be significantly more expensive than the cost of a soil/bentonite slurry wall.

Sheet Piling

Sheet piling can also be used to construct a vertical barrier to ground water movement. The sheet piles are driven into the ground, with interlocking edges which provide a sealing mechanism. Sheet pile walls require little maintenance and can be coated (e.g., galvanized or polymer-coated) to protect the metal in corrosive environments. The presence of subsurface rocks and boulders can complicate installation, resulting in potential damage to or deflection of the sheet piles.

Extraction

Extraction technology provides a means to collect contaminated ground water or leachate at a site. Various means of extraction include extraction wells, well points, or interceptor trenches.

Extraction Wells

Extraction wells represent a conventional technology which is frequently used in the removal of contaminated ground water. Stainless steel or PVC well casings and screens are installed within the contaminated ground water, and submersible pumps are typically used to extract water from the well. An array of wells with overlapping radii of influence can be designed to capture an entire plume or to halt contaminant migration.

Well Points

This ground water extraction technology involves the removal of ground water through a group of closely spaced wells connected by a header pipe. The wells are installed by driving a perforated pipe with a pointed cap into the area to be dewatered. Well point systems are best suited for shallow aquifers where extraction is not needed below twenty feet. The suction lifting pump technique commonly employed with well points is ineffective beyond this depth. Due to the presence of the water table at depths of up to 20 feet at Site 09, this technology has been screened from further evaluation.

Interceptor Trench

Interceptor trenches may be employed as a means of collecting ground water through the use of a perforated pipe placed below the natural ground water table. Ground water enters the perforated pipe and flows by gravity to the lowest point in the pipe, where it is pumped to the surface for treatment and/or discharge. This technology is typically limited to areas where the depth to ground water is not so deep that trench construction becomes prohibitively expensive or complicated (bracing, etc.). This technology offers the advantage of a horizontally oriented intake structure which allows collection of ground water within the area of interest. Additionally, trenches are relatively simple to construct and are passive structures with little maintenance required. Due to the presence of the water table at depths of up to 20 feet at Site 09, and the potential difficulty of excavating to greater depths in mixed soil/waste materials, this technology has been screened from further evaluation.

Off-Site Treatment

Off-site treatment utilizes an off-site facility to treat extracted ground water. The contaminated ground water must be transported or conveyed to the treatment facility. Costs associated with conveyance or transportation can be extremely expensive if the distance from the site to the off-site treatment facility is far. Two types of off-site treatment facilities include publicly owned treatment works (POTW) and RCRA treatment facilities.

Off-Site Treatment at a POTW

This technology involves the discharge of aqueous wastes, which can constitute the majority of waste treated during a remedial cleanup effort, from a site to a Publicly Owned Treatment Works (POTW) for off-site treatment. These aqueous wastes can include ground water, leachate, surface water runoff, or other aqueous wastes. A number of criteria must be met when utilizing a POTW. These restrictions, as they apply to CERCLA sites, are detailed in the U.S. EPA's CERCLA Site Discharges to POTWs: Guidance Manual (U.S. EPA, 1990a).

Typically, the proximity of a POTW to the site is such that the wastes can be piped to the POTW. Due to the presence of organic contaminants within the ground water which may not be treatable using standard POTW treatment processes, off-site treatment at a POTW will be screened from further consideration. Treatment at a POTW may be appropriate as a remedial technology if combined with on-site pretreatment. Therefore, discharge of treated ground water to a POTW will be further evaluated with respect to discharge process options (as discussed later in this presentation)

Off-Site Treatment at a RCRA Facility

Discharge to a RCRA facility also represents a potential off-site treatment technology for remediating contaminated ground water and other aqueous wastes. The extracted ground water is collected and transported off-site to a licensed RCRA facility for treatment. High extraction rates and the distance to the nearest RCRA treatment facility can greatly limit the cost-effectiveness of this alternative. This technology is screened from further consideration based on the lack of a locally available RCRA treatment facility.

Biological Organic Treatment

Biological water treatment methods have been well proven in their application at municipal wastewater treatment facilities. Recently, their application to the treatment of hazardous wastes has been evaluated. Biological treatment removes organic matter from the wastestream through biological degradation.

The most prevalent form of biological treatment is aerobic (i.e., in the presence of oxygen). Aerobic biological treatment can be effective for the treatment of aromatic hydrocarbons, polynuclear aromatic hydrocarbons, and phenols. The wastestream's biological oxygen demand (BOD) can provide an indication of the treatability of the waste by aerobic treatment.

Specialized biological treatment systems are being developed for specific contaminants not treatable under normal aerobic conditions. Such systems utilize contaminant-specific bacteria or special environmental conditions to enhance the biodegradation of the target contaminants.

Bioreactor

A bioreactor typically utilizes an activated sludge process to treat wastes, although design variations using fixed film treatment exist. Acclimated bacteria aerobically degrade contaminants. Bioreactors have been successful in the treatment of industrial wastewaters and ground water with organic contaminants.

Powdered Activated Carbon Treatment

Powdered activated carbon treatment is a treatment process where powdered activated carbon is added to a traditional aerated biological treatment process. Treatment is achieved both through the biological degradation of contaminants and the adsorption of non-degradable contaminants onto the carbon. Anaerobic and multi-staged aerobic-anaerobic treatment systems are also available. The technology has successfully been applied to the treatment of industrial wastewaters and ground water and leachates containing hazardous organic pollutants.

Physical Organic Treatment

In physical treatment, the physical properties of the wastestream are used to effect the removal of the contamination. Physical process such as volatilization and adsorption typically drive the physical treatment processes.

Air Stripping

Air stripping is a physical treatment method which consists of the mass transfer of a volatile chemical from a liquid phase to a vapor phase by bringing a flow of air into contact with the liquid. Air strippers come in a variety of configurations, but the basic principle behind their operation is the same for each type.

The most common configuration in ground water treatment is the countercurrent packed tower, in which contaminated water is trickled downward over rings, spheres, or other types of packing material in a stainless steel, fiberglass, or PVC cylinder. Clean air is blown upward through the tower, volatilizing contaminants and exhausting them out the top. Air stripping is effective with contaminants exhibiting high Henry's law constants, which relate equilibrium concentrations of a chemical compound in liquid and gas phases. Volatile contaminants susceptible to air stripping include aromatic hydrocarbons and chlorinated organics. Removal efficiencies can vary widely depending on types of contaminant, influent concentrations, stripper design, temperature, and a number of other factors. However, a properly designed and operated air stripper can be expected to achieve greater than 95% removal efficiency for volatile contaminants (Canter, et al., 1986).

Emission controls on the stripping column are often required to collect exhausted contaminants. Although this reduces the simplicity of the system, small carbon adsorption units can be connected to the gaseous outflow to capture contaminants. Environmental effects of exhausted contaminants are probably minimal, since most volatile organic compounds have atmospheric half-lives (time to degrade 50% of the contaminant) on the order of minutes or hours (Cuppitt, 1980).

Steam Stripping

Steam stripping differs from air stripping by the injection of steam, as opposed to air, into a tray or packed distillation column in order to remove volatile organic chemicals from waste streams. This type of process option is most effectively applied to aqueous solutions for the removal of volatile organic compounds that are immiscible in water. Steam stripping is more economical and effective than air stripping for treating wastes with high concentrations of volatiles and wastes with contaminants which have a low volatility (Surprenant, 1988). In regard to the specific treatment process, the waste stream enters near the top of the column and then flows by gravity countercurrent to the steam. As the waste stream passes down through the column, volatile compounds within the waste stream are lost to the steam/organic vapor stream rising from the bottom of the column. The concentration of volatile compounds in the waste stream reaches a minimum at the bottom of the column. The overhead vapor is condensed as it exits the column and the condensate is then decanted to achieve water/solvent separation.

Carbon Adsorption

One of the most frequently applied technologies for the removal of low concentrations of organics from waste streams is carbon adsorption. The process consists of bringing contaminated ground water in contact with a bed of granular activated carbon (GAC), where contaminants are held by physical and/or chemical forces on the activated surface of the carbon itself. The system is usually configured as one or several columns in series which are filled with activated carbon. Carbon adsorption is effective with a wide variety of organic contaminants, but the performance of the process can be influenced by pH, the adsorptive capacity of the carbon, and temperature. Removal efficiencies of greater than 99% can be expected (Canter, et al., 1986).

Spent activated carbon (carbon which has reached its adsorption capacity) must be regenerated through the application of heat. This usually entails removal of carbon from the unit for regeneration at an off-site incinerator. Operation of units in series prevents shutoff of the entire system during regeneration.

Resin Adsorption

Resin adsorption represents another physical treatment option for the removal of organic contaminants from aqueous waste streams. The operation of resin adsorption is similar to that of carbon adsorption. Specifically, organic molecules contacting the resin surface are held on the surface by physical forces and are subsequently removed during the resin regeneration cycle. Even though the process operation of resin adsorption is similar to carbon adsorption, many aspects of the two technologies differ. For example, the bonding forces in resin adsorption are usually weaker than those encountered in granulated activated carbon adsorption and therefore, resins may be regenerated chemically rather than thermally, as carbon adsorption systems must be regenerated. Resins generally have a lower adsorption capacity than carbon. Resin adsorption is most practical for treatment of colored organic wastes, when material recovery is practical, where selective adsorption is desired, where low leakage rates are required, where carbon regeneration is not practical and where the wastestream contains high levels of dissolved inorganic solids (Berkowitz, et al., 1978).

Chemical Organic Treatment

Chemical treatment utilizes chemical processes and reactions to remove contaminants from a wastestream.

Ultraviolet (UV) Oxidation

UV oxidation is a chemical process which utilizes an oxidant in combination with ultraviolet radiation to treat specific waste streams containing phenols, cyanides, chlorinated hydrocarbons, organic sulfur compounds, and other rapidly oxidized organics. This process option transforms the contaminants into a less hazardous form. When reactions are carried to completion, halogenated compounds are converted to carbon dioxide, water, and residual halides. Treatment data indicate that destruction of organic contaminants to non-detectable levels is achieved within minutes (Hager, et al., 1987). UV oxidation is especially effective in the treatment of chlorinated volatile organics, although it is less effective in treating single-bonded hydrocarbons such as 1,1,1-trichloroethane.

Inorganic Treatment

Inorganic treatment typically involve physical or chemical treatment, as discussed below.

Ion Exchange

Ion exchange is a process whereby the toxic ions are removed from the aqueous phase by being exchanged with relatively harmless ions held by the ion exchange material. Ion exchange is a well established technology for removal of heavy metals and hazardous anions from dilute solutions. Ion exchange can be expected to perform well for these applications when fed wastes of variable composition, provided the system's effluent is continually monitored to determine when the resin bed exhaustion has occurred. However, the reliability of ion exchange is markedly affected by the presence of suspended solids.

Ion exchange systems are commercially available from a number of vendors. The units are relatively compact and are not energy intensive. Although exchange columns can be operated manually or automatically, manual operation is better suited for hazardous waste site applications because of the diversity of wastes encountered. In addition, use of several exchange columns at a site can provide considerable flexibility.

Precipitation

Precipitation is a physicochemical process whereby some or all of a substance in solution is transformed into a solid phase. It is based on alteration of the chemical equilibrium relationships affecting the solubility of inorganic species. Removal of metals as hydroxides or sulfides is the most common precipitation application in wastewater treatment. Generally, lime or sodium sulfide is added to the wastewater in a rapid mixing tank along with flocculating agents. The wastewater flows to a flocculating chamber in which adequate mixing and retention time is provided for agglomeration of precipitate particles. Agglomerated particles are separated from the liquid phase by settling in a sedimentation chamber, and/or by other physical processes such as filtration.

Membrane Microfiltration

Membrane microfiltration involves the use of an automatic pressure filter in which the filter material has tiny openings (0.10 microns or 1 ten-millionth of a meter) which allow for the filtration of particles normally not separated from the wastestream using standard filtration processes. Membrane microfiltration is most applicable to hazardous waste suspensions, ground water contaminated with heavy metals, landfill leachate and process wastewaters containing uranium (U.S. EPA, 1991).

Filtration

Filtration is a type of physical separation of a solid material based on particle size. As commonly employed in ground water treatment, filtration involves the separation of suspended solids, primarily silt, from the influent stream. Filters generally work on the same principal as a domestic vacuum cleaner whereby particles are intercepted in a fabric. Fabric size, particle size, and density differences each play a role in the proper selection of a filtration device.

Electrochemical

Electrochemical treatment provides treatment of inorganic contaminants. Contaminated water passes through an electrochemical cell where ferrous ions, hydroxide ions and hydrogen are produced. The ferrous ions act as reducing agents for oxidized heavy metals and also react with the hydroxide ions, forming iron hydroxides and metal hydroxides. The metal hydroxides are removed by adsorption onto the iron hydroxide precipitate that is formed (Hazardous Waste Consultant, 1991).

In-Situ Treatment

In-situ treatment technologies provide treatment of contaminated media without physical extraction. Two types of in-situ ground water treatment technologies include air sparging and biodegradation.

Air Sparging

Air sparging involves the injection of air into special air injection wells. The air then "bubbles" up through the saturated subsurface soils into the unsaturated zone. As the air passes through the contaminated ground water in the saturated zone, it strips volatile organic contaminants from the ground water. The contaminants enter the vapor phase of the unsaturated zone and are then removed using conventional vapor extraction technology. This technology has not been widely proven and its effectiveness in treating contaminated ground water is not well demonstrated. Due to the depth at which elevated organic contaminant levels were detected at Site 09 (especially at well 09-MW7D) and the heterogeneous nature of the subsurface fill materials which could affect the passage of the air through the subsurface materials, air sparging is screened from further consideration for treatment of ground water/leachate at Site 09.

Biodegradation

In the biodegradation process, nutrients and/or enhanced microorganisms are added to contaminated media to augment natural biodegradation. Biodegradation is effective for fuel products, but is generally limited to geologies which favor aerobic conditions. Due to the variety of ground water/leachate contaminants and the variability of subsurface conditions which would affect the subsurface transport of nutrients, this process option is screened from further consideration at Site 09.

Discharge

Following treatment, extracted ground water must be discharged back to the environment. Several options exist for the discharge of ground water, as described below.

Discharge to Ground Water

Treated ground water can be discharged to ground water using recharge basins, infiltration galleries or reinjection wells. The technology selected for recharge is dependent on site-specific considerations such as available space, extent of contamination, and hydrogeology. Ground water recharge systems can provide an added element of hydraulic control to ground water extraction systems. Typically recharge systems can be subject to clogging or other operational problems and must be closely monitored. Compliance with ground water discharge regulations must also be maintained. At Site 09, it would be preferable to recharge treated ground water at a location where it would not come into additional contact with buried waste materials.

Discharge to Surface Water

Treated ground water can also be discharged to a surface water body. This technology would technically be easy to implement, given the proximity of Allen Harbor to the site. It requires compliance with NPDES discharge requirements.

Discharge to Sanitary Sewer/POTW

If available nearby, discharge of treated or untreated ground water to a sanitary sewer for subsequent treatment at a Publicly Owned Treatment Works (POTW) is a possible alternative. Many POTWs have regulations prohibiting discharges of ground water to the treatment system and special approval for such a discharge may be required. The POTW may also require pretreatment of the wastestream prior to acceptance. An additional concern of POTWs in accepting a discharge from a CERCLA site is the issue of whether the POTW is then considered a hazardous waste treatment facility. Therefore, the administrative acceptability of discharging water to a POTW may be limited.

APPENDIX E

REMEDIAL COST ESTIMATES

Cost estimates are provided for the following alternatives:

SOIL/WASTE ALTERNATIVES

Alternative S/W-2, Deed Restrictions and Fencing

Alternative S/W-3A, Native Soil Cap

Alternative S/W-3B, RCRA Subtitle C Hybrid Soil Cap

Alternative S/W-3B, RCRA Subtitle C Hybrid Soil Cap (without stone revetment)

Alternative S/W-3C, RCRA Subtitle C Landfill Cap

Alternative S/W-3C, RCRA Subtitle C Landfill Cap (without stone revetment)

GROUND WATER/LEACHATE ALTERNATIVES

Alternative GW-2A, Long-Term Monitoring

Alternative GW-3B, Sheet Piling Vertical Barrier

Alternative GW-4A, Ground Water Extraction

Alternative GW-4B, Air Stripping

Alternative GW-4C, UV Oxidation

Alternative GW-4D, Chemical Precipitation

Alternative GW-4E, Membrane Microfiltration

Alternative GW-4F, Discharge to Surface Water

SEDIMENT ALTERNATIVES

Alternative SD-2, Limited Action

Alternative SD-3, Containment

ALTERNATIVE S/W-2
DEED RESTRICTIONS AND FENCING
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST – DIRECT										
Fencing										
– Chain Link , 9 gauge wire, aluminized steel, 6' high	3,700	l. ft.	$13.75	1994	2	1.000	$13.75	$50,875.00		
– Double Swing Gate 6' high, 20' opening	1	each	$905.00	1994	2	1.000	$905.00	$905.00		
– Warning Signs	37	each	$45.50	1994	2	1.000	$45.50	$1,683.50		
Total Fencing Cost										$53,463.50
Direct Capital Cost Subtotal										$53,463.50
CAPITAL COSTS – INDIRECT										
Engineering and Design (10%)					1			$5,346.35		
Legal and Administrative (4%)					1			$2,138.54		
Indirect Capital Cost Total										$7,484.89
TOTAL CAPITAL COSTS										$60,948.39
OPERATION AND MAINTENANCE COSTS										
Site Fence Maintenance	1	each	$500.00	1988	3	1.188	$594.00	$594.00	30	$9,130.97
Surface Water Discharge Monitoring										
– Collection and Reporting	1	lump sum	$15,000.00	1994	5	1.000	$15,000.00	$15,000.00	30	$230,580.00
– Sample Analysis	2	each	$1,630.00	1993	10	1.031	$1,680.53	$3,361.06	30	$51,666.21
ANNUAL O & M COST								$18,955.06		
TOTAL NET PRESENT VALUE OF O & M										$291,377.18
SUBTOTAL COST										$352,325.57
CONTINGENCY (20%)										$70,465.11
TOTAL PRESENT VALUE COST FOR ALTERNATIVE S/W-2										$422,790.69

(1) – Calculated based on 5% interest rate.

ALTERNATIVE S/W-3, OPTION A
NATIVE SOIL CAP
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST – DIRECT										
Permitting and Regulatory Approvals	1	lump sum	$50,000.00	1993	12	1.031	$51,550.00	$51,550.00		
Site Preparation										
– Clear Vegetation and Brush	13.5	acres	$2,775.00	1994	2	1.000	$2,775.00	$37,462.50		
– Regrade Site and Cutback Slopes	44,450	cu. yd.	$5.00	1994	2	1.000	$5.00	$222,250.00		
– Health and Safety (17%)								$44,151.13		
Total Site Preparation Cost										$355,413.63
Native Soil Cap Construction										
– 6" Topsoil	11,111	cu. yd.	$14.50	1994	5	1.000	$14.50	$161,109.50		
– 4.5' Native Soil	99,999	cu. yd.	$9.75	1994	5	1.000	$9.75	$974,990.25		
– Seed, Fertilizer, Mulch	600	msf	$45.50	1994	2	1.000	$45.50	$27,300.00		
– Health & Safety (17%)					4			$170,389.34		
Total Soil Cap Construction Cost										$1,333,789.09
Site Survey	1	lump sum	$5,000.00	1994	2	1.000	$5,000.00	$5,000.00		$5,000.00
Equipment Decontamination										
– Rental of Steam Cleaner	3	months	$425.00	1994	2	1.000	$425.00	$1,275.00		
– Construction of Decon Pit										
Excavate Pit	15	cu. yd.	$3.82	1994	2	1.000	$3.82	$57.30		
Polyethylene Tarpaulin	400	sq. ft.	$0.35	1994	2	1.000	$0.35	$140.00		
– Tanker Truck Rental	3	months	$650.00	1994	5	1.000	$650.00	$1,950.00		
– Disposal (Tanker Truck)	1	each	$1,600.00	1992	11	1.077	$1,723.20	$1,723.20		
Total Equipment Decontamination Cost										$5,145.50

ALTERNATIVE S/W-3, OPTION A
NATIVE SOIL CAP
SITE 09 – ALLEN HARBOR LANDFILL
(continued)

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
Dust Control										
– Water Tank Sprayer	3	months	$2,075.00	1994	2	1.000	$2,075.00	$6,225.00		$6,225.00
Engineering Mgmt. Mob/Demob										
– 2 Trailers	3	months	$900.00	1994	2	1.000	$900.00	$2,700.00		$2,700.00
Direct Capital Cost Subtotal										$1,708,273.22
CAPITAL COST – INDIRECT										
Engineering and Design (10%)					1			$170,827.32		
Legal and Administrative (4%)					1			$68,330.93		
Total Indirect Capital Cost										$239,158.25
TOTAL CAPITAL COSTS										$1,947,431.47
OPERATION AND MAINTENANCE COSTS										
Soil Cap O & M										
– Cap Annual Inspection and Repairs	1	each	$1,000.00	1988	7	1.188	$1,188.00	$1,188.00	30	$18,261.94
Surface Water Discharge Monitoring										
– Collection and Reporting	1	lump sum	$15,000.00	1994	5	1.000	$15,000.00	$15,000.00	30	$230,580.00
– Sample Analysis	2	each	$1,630.00	1993	10	1.031	$1,680.53	$3,361.06	30	$51,666.21
ANNUAL O&M COST								$19,549.06		
TOTAL NET PRESENT VALUE OF O & M										$300,508.15
SUBTOTAL COST										$2,247,939.62
CONTINGENCY (20%)										$449,587.92
TOTAL PRESENT VALUE COST FOR ALTERNATIVE S/W-3, OPTION A										$2,697,527.54

(1) – Calculated based on 5% interest rate.

ALTERNATIVE S/W-3, OPTION B
RCRA SUBTITLE C HYBRID SOIL CAP
SITE 09 - ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT										
Permitting and Regulatory Approvals	1	lump sum	$50,000.00	1993	12	1.031	$51,550.00	$51,550.00		
Landfill Gas Management Analysis	1	lump sum	$50,000.00	1993	12	1.031	$51,550.00	$51,550.00		
Site Preparation										
- Clear Vegetation and Brush	13.5	acres	$2,775.00	1994	2	1.000	$2,775.00	$37,462.50		
- Regrade Site and Cutback Slopes	44,450	cu. yd.	$5.00	1994	2	1.000	$5.00	$222,250.00		
- Health and Safety (17%)								$44,151.13		
Total Site Preparation Cost										$406,963.63
Hybrid Cap Construction										
- 12" Bedding Layer	22,222	cu. yd.	$14.50	1994	5	1.000	$14.50	$322,219.00		
- Geomembrane	600,000	sq. ft.	$0.68	1994	21	1.000	$0.68	$408,000.00		
- Geonet	600,000	sq. ft.	$0.39	1994	21	1.000	$0.39	$234,000.00		
- 18" Vegetative Support Soil Layer	33,333	cu. yd.	$9.75	1994	5	1.000	$9.75	$324,996.75		
- 6" Topsoil Layer	11,111	cu. yd.	$14.50	1994	5	1.000	$14.50	$161,109.50		
- Seed, Fertilizer, Mulch	600	msf	$45.50	1994	2	1.000	$45.50	$27,300.00		
- Health & Safety (17%)					4			$87,279.06		
Total Soil Cap Construction Cost										$1,564,904.31
Surface Controls										
- Stone Revetment	5,535	sq. yd.	$58.00	1994	2	1.000	$58.00	$321,030.00		
- Health & Safety (17%)								$54,575.10		
- Cut Drainage Ditches	3,700	l. ft.	$1.00	1988	3	1.188	$1.19	$4,395.60		
- Riprap (slope protection)	1,370	cu. yd.	$28.50	1994	2	1.000	$28.50	$39,045.00		
Total Surface Controls										$419,045.70
Site Survey	1	lump sum	$5,000.00	1994	2	1.000	$5,000.00	$5,000.00		$5,000.00
Equipment Decontamination										
- Rental of Steam Cleaner	8	months	$425.00	1994	2	1.000	$425.00	$3,400.00		
- Construction of Decon Pit										
Excavate Pit	15	cu. yd.	$3.82	1994	2	1.000	$3.82	$57.30		
Polyethylene Tarpaulin	400	sq. ft.	$0.35	1994	2	1.000	$0.35	$140.00		
- Tanker Truck Rental	8	months	$650.00	1994	5	1.000	$650.00	$5,200.00		
- Disposal (Tanker Truck)	1	each	$1,600.00	1992	13	1.077	$1,723.20	$1,723.20		
Total Equipment Decontamination Cost										$10,520.50

ALTERNATIVE S/W-3, OPTION B
RCRA SUBTITLE C HYBRID SOIL CAP
SITE 09 - ALLEN HARBOR LANDFILL
(continued)

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
Dust Control										
- Water Tank Sprayer	8	months	$2,075.00	1994	2	1.000	$2,075.00	$16,600.00		$16,600.00
Engineering Mgmt. Mob/Demob										
- 2 Trailers	8	months	$900.00	1994	2	1.000	$900.00	$7,200.00		$7,200.00
Direct Capital Cost Subtotal										$2,430,234.14
CAPITAL COST - INDIRECT										
Engineering and Design (10%)					1			$243,023.41		
Legal and Administrative (4%)					1			$97,209.37		
Total Indirect Capital Cost										$340,232.78
TOTAL CAPITAL COSTS										$2,770,466.92
OPERATION AND MAINTENANCE COSTS										
Soil Cap O & M										
- Cap Annual Inspection and Repairs	1	each	$5,000.00	1988	7	1.188	$5,940.00	$5,940.00	30	$91,309.68
Surface Water Discharge Monitoring										
- Collection and Reporting	1	lump sum	$15,000.00	1994	5	1.000	$15,000.00	$15,000.00	30	$230,580.00
- Sample Analysis	2	each	$1,630.00	1993	10	1.031	$1,680.53	$3,361.06	30	$51,666.21
ANNUAL O&M COST								$24,301.06		
TOTAL NET PRESENT VALUE OF O & M										$373,555.89
SUBTOTAL COST										$3,144,022.81
CONTINGENCY (20%)										$628,804.56
TOTAL PRESENT VALUE COST FOR ALTERNATIVE S/W-3, OPTION B										$3,772,827.37

(1) - Calculated based on 5% interest rate.

ALTERNATIVE S/W–3, OPTION B (without stone revetment)
RCRA SUBTITLE C HYBRID SOIL CAP
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST – DIRECT										
Permitting and Regulatory Approvals	1	lump sum	$50,000.00	1993	12	1.031	$51,550.00	$51,550.00		
Landfill Gas Management Analyses	1	lump sum	$50,000.00	1993	12	1.031	$51,550.00	$51,550.00		
Site Preparation										
– Clear Vegetation and Brush	13.5	acres	$2,775.00	1994	2	1.000	$2,775.00	$37,462.50		
– Regrade Site and Cutback Slopes	44,450	cu. yd.	$5.00	1994	2	1.000	$5.00	$222,250.00		
– Health and Safety (17%)								$44,151.13		
Total Site Preparation Cost										$406,963.63
Hybrid Cap Construction										
– 12" Bedding Layer	22,222	cu. yd.	$14.50	1994	5	1.000	$14.50	$322,219.00		
– Geomembrane	600,000	sq. ft.	$0.68	1994	21	1.000	$0.68	$408,000.00		
– Geonet	600,000	sq. ft.	$0.39	1994	21	1.000	$0.39	$234,000.00		
– 18" Vegetative Support Soil Layer	33,333	cu. yd.	$9.75	1994	5	1.000	$9.75	$324,996.75		
– 6" Topsoil Layer	11,111	cu. yd.	$14.50	1994	5	1.000	$14.50	$161,109.50		
– Seed, Fertilizer, Mulch	600	msf	$45.50	1994	2	1.000	$45.50	$27,300.00		
– Health & Safety (17%)					4			$87,279.06		
Total Soil Cap Construction Cost										$1,564,904.31
Surface Controls										
– Cut Drainage Ditches	3,700	l. ft.	$1.00	1988	3	1.188	$1.19	$4,395.60		
– Riprap (slope protection)	1,370	cu. yd.	$28.50	1994	2	1.000	$28.50	$39,045.00		
Total Surface Controls										$43,440.60
Site Survey	1	lump sum	$5,000.00	1994	2	1.000	$5,000.00	$5,000.00		$5,000.00

ALTERNATIVE S/W–3, OPTION B (without stone revetment)
RCRA SUBTITLE C HYBRID SOIL CAP
SITE 09 – ALLEN HARBOR LANDFILL
(continued)

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
Equipment Decontamination										
– Rental of Steam Cleaner	8	months	$425.00	1994	2	1.000	$425.00	$3,400.00		
– Construction of Decon Pit										
Excavate Pit	15	cu. yd.	$3.82	1994	2	1.000	$3.82	$57.30		
Polyethylene Tarpaulin	400	sq. ft.	$0.35	1994	2	1.000	$0.35	$140.00		
– Tanker Truck Rental	8	months	$650.00	1994	5	1.000	$650.00	$5,200.00		
– Disposal (Tanker Truck)	1	each	$1,600.00	1992	13	1.077	$1,723.20	$1,723.20		
Total Equipment Decontamination Cost										$10,520.50
Dust Control										
– Water Tank Sprayer	8	months	$2,075.00	1994	2	1.000	$2,075.00	$16,600.00		$16,600.00
Engineering Mgmt. Mob/Demob										
– 2 Trailers	8	months	$900.00	1994	2	1.000	$900.00	$7,200.00		$7,200.00
Direct Capital Cost Subtotal										$2,054,629.04
CAPITAL COST – INDIRECT										
Engineering and Design (10%)					1			$205,462.90		
Legal and Administrative (4%)					1			$82,185.16		
Total Indirect Capital Cost										$287,648.07
TOTAL CAPITAL COSTS										$2,342,277.10
OPERATION AND MAINTENANCE COSTS										
Soil Cap O & M										
– Cap Annual Inspection and Repairs	1	each	$5,000.00	1988	7	1.188	$5,940.00	$5,940.00	30	$91,309.68
Surface Water Discharge Monitoring										
– Collection and Reporting	1	lump sum	$15,000.00	1994	5	1.000	$15,000.00	$15,000.00	30	$230,580.00
– Sample Analysis	2	each	$1,630.00	1993	10	1.031	$1,680.53	$3,361.06	30	$51,666.21
ANNUAL O&M COST								$24,301.06		
TOTAL NET PRESENT VALUE OF O & M										$373,555.89
SUBTOTAL COST										$2,715,833.00
CONTINGENCY (20%)										$543,166.60
TOTAL PRESENT VALUE COST FOR ALTERNATIVE S/W–3, OPTION B (without stone revetment)										$3,258,999.60

(1) – Calculated based on 5% interest rate.

ALTERNATIVE S/W-3, OPTION C
RCRA SUBTITLE C LANDFILL CAP
SITE 09 - ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
<u>CAPITAL COST - DIRECT</u>										
Permitting and Regulatory Approvals	1	lump sum	$50,000.00	1993	12	1.031	$51,550.00	$51,550.00		
Landfill Gas Management Analysis	1	lump sum	$50,000.00	1993	12	1.031	$51,550.00	$51,550.00		
Site Preparation										
- Clear Vegetation and Brush	13.5	acres	$2,775.00	1994	2	1.000	$2,775.00	$37,462.50		
- Regrade Site and Cutback Slopes	44,450	cu. yd.	$5.00	1994	2	1.000	$5.00	$222,250.00		
- Health and Safety (17%)								$44,151.13		
Total Site Preparation Cost										$406,963.63
Landfill Cap Construction										
- 12" Bedding Layer	22,222	cu. yd.	$14.50	1994	5	1.000	$14.50	$322,219.00		
- 2' Barrier Layer	44,444	cu. yd.	$25.00	1993	12	1.031	$25.78	$1,145,544.10		
- Geomembrane	600,000	sq. ft.	$0.68	1994	21	1.000	$0.68	$408,000.00		
- Geonet	600,000	sq. ft.	$0.39	1994	21	1.000	$0.39	$234,000.00		
- 18" Vegetative Support Soil Layer	33,333	cu. yd.	$9.75	1994	5	1.000	$9.75	$324,996.75		
- 6" Topsoil Layer	11,111	cu. yd.	$14.50	1994	5	1.000	$14.50	$161,109.50		
- Seed, Fertilizer, Mulch	600	msf	$45.50	1994	2	1.000	$45.50	$27,300.00		
- Health & Safety (17%)					4			$87,279.06		
Total Landfill Cap Construction Cost										$2,710,448.41
Surface Controls										
- Stone Revetment	5,535	sq. yd.	$58.00	1994	2	1.000	$58.00	$321,030.00		
- Health & Safety (17%)								$54,575.10		
- Cut Drainage Ditches	3,650	l. ft.	$1.00	1988	3	1.188	$1.19	$4,336.20		
- Riprap (slope protection)	1,352	cu. yd.	$28.50	1994	2	1.000	$28.50	$38,532.00		
Total Surface Controls										$418,473.30
Site Survey	1	lump sum	$5,000.00	1994	2	1.000	$5,000.00	$5,000.00		$5,000.00

ALTERNATIVE S/W-3, OPTION C
RCRA SUBTITLE C LANDFILL CAP
SITE 09 - ALLEN HARBOR LANDFILL
(continued)

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
Equipment Decontamination										
- Rental of Steam Cleaner	10	months	$425.00	1994	2	1.000	$425.00	$4,250.00		
- Construction of Decon Pit										
Excavate Pit	15	cu. yd.	$3.82	1994	2	1.000	$3.82	$57.30		
Polyethylene Tarpaulin	400	sq. ft.	$0.35	1994	2	1.000	$0.35	$140.00		
- Tanker Truck Rental	10	months	$650.00	1994	5	1.000	$650.00	$6,500.00		
- Disposal (Tanker Truck)	1	each	$1,600.00	1992	13	1.077	$1,723.20	$1,723.20		
Total Equipment Decontamination Cost										$12,670.50
Dust Control										
- Water Tank Sprayer	10	months	$2,075.00	1994	2	1.000	$2,075.00	$20,750.00		$20,750.00
Engineering Mgmt. Mob/Demob										
- 2 Trailers	10	months	$900.00	1994	2	1.000	$900.00	$9,000.00		$9,000.00
Direct Capital Cost Subtotal										$3,583,305.84
CAPITAL COST - INDIRECT										
Engineering and Design (10%)					1			$358,330.58		
Legal and Administrative (4%)					1			$143,332.23		
Total Indirect Capital Cost										$501,662.82
TOTAL CAPITAL COSTS										$4,084,968.65
OPERATION AND MAINTENANCE COSTS										
Soil Cap O & M										
- Cap Annual Inspection and Repairs	1	each	$5,000.00	1988	7	1.188	$5,940.00	$5,940.00	30	$91,309.68
Surface Water Discharge Monitoring										
- Collection and Reporting	1	lump sum	$15,000.00	1994	5	1.000	$15,000.00	$15,000.00	30	$230,580.00
- Sample Analysis	2	each	$1,630.00	1993	10	1.031	$1,680.53	$3,361.06	30	$51,666.21
ANNUAL O&M COST								$24,301.06		
TOTAL NET PRESENT VALUE OF O & M										$373,555.89
SUBTOTAL COST										$4,458,524.55
CONTINGENCY (20%)										$891,704.91
TOTAL PRESENT VALUE COST FOR ALTERNATIVE S/W-3, OPTION C										$5,350,229.46

(1) - Calculated based on 5% interest rate.

ALTERNATIVE S/W–3, OPTION C (without stone revetment)
RCRA SUBTITLE C LANDFILL CAP
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST – DIRECT										
Permitting and Regulatory Approvals	1	lump sum	$50,000.00	1993	12	1.031	$51,550.00	$51,550.00		
Landfill Gas Management Analysis	1	lump sum	$50,000.00	1993	12	1.031	$51,550.00	$51,550.00		
Site Preparation										
– Clear Vegetation and Brush	13.5	acres	$2,775.00	1994	2	1.000	$2,775.00	$37,462.50		
– Regrade Site and Cutback Slopes	44,450	cu. yd.	$5.00	1994	2	1.000	$5.00	$222,250.00		
– Health and Safety (17%)								$44,151.13		
Total Site Preparation Cost										$406,963.63
Landfill Cap Construction										
– 12" Bedding Layer	22,222	cu. yd.	$14.50	1994	5	1.000	$14.50	$322,219.00		
– 2' Barrier Layer	44,444	cu. yd.	$25.00	1993	12	1.031	$25.78	$1,145,544.10		
– Geomembrane	600,000	sq. ft.	$0.68	1994	21	1.000	$0.68	$408,000.00		
– Geonet	600,000	sq. ft.	$0.39	1994	21	1.000	$0.39	$234,000.00		
– 18" Vegetative Support Soil Layer	33,333	cu. yd.	$9.75	1994	5	1.000	$9.75	$324,996.75		
– 6" Topsoil Layer	11,111	cu. yd.	$14.50	1994	5	1.000	$14.50	$161,109.50		
– Seed, Fertilizer, Mulch	600	msf	$45.50	1994	2	1.000	$45.50	$27,300.00		
– Health & Safety (17%)					4			$87,279.06		
Total Landfill Cap Construction Cost										$2,710,448.41
Surface Controls										
– Cut Drainage Ditches	3,700	l. ft.	$1.00	1988	3	1.188	$1.19	$4,395.60		
– Riprap (slope protection)	1,352	cu. yd.	$28.50	1994	2	1.000	$28.50	$38,532.00		
Total Surface Controls										$42,927.60
Site Survey	1	lump sum	$5,000.00	1994	2	1.000	$5,000.00	$5,000.00		$5,000.00

ALTERNATIVE S/W–3, OPTION C (without stone revetment)
RCRA SUBTITLE C LANDFILL CAP
SITE 09 – ALLEN HARBOR LANDFILL
(continued)

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
Equipment Decontamination										
– Rental of Steam Cleaner	10	months	$425.00	1994	2	1.000	$425.00	$4,250.00		
– Construction of Decon Pit										
Excavate Pit	15	cu. yd.	$3.82	1994	2	1.000	$3.82	$57.30		
Polyethylene Tarpaulin	400	sq. ft.	$0.35	1994	2	1.000	$0.35	$140.00		
– Tanker Truck Rental	10	months	$650.00	1994	5	1.000	$650.00	$6,500.00		
– Disposal (Tanker Truck)	1	each	$1,600.00	1992	13	1.077	$1,723.20	$1,723.20		
Total Equipment Decontamination Cost										$12,670.50
Dust Control										
– Water Tank Sprayer	10	months	$2,075.00	1994	2	1.000	$2,075.00	$20,750.00		$20,750.00
Engineering Mgmt. Mob/Demob										
– 2 Trailers	10	months	$900.00	1994	2	1.000	$900.00	$9,000.00		$9,000.00
Direct Capital Cost Subtotal										$3,207,760.14
CAPITAL COST – INDIRECT										
Engineering and Design (10%)					1			$320,776.01		
Legal and Administrative (4%)					1			$128,310.41		
Total Indirect Capital Cost										$449,086.42
TOTAL CAPITAL COSTS										$3,656,846.56
OPERATION AND MAINTENANCE COSTS										
Soil Cap O & M										
– Cap Annual Inspection and Repairs	1	each	$5,000.00	1988	7	1.188	$5,940.00	$5,940.00	30	$91,309.68
Surface Water Discharge Monitoring										
– Collection and Reporting	1	lump sum	$15,000.00	1994	5	1.000	$15,000.00	$15,000.00	30	$230,580.00
– Sample Analysis	2	each	$1,630.00	1993	10	1.031	$1,680.53	$3,361.06	30	$51,666.21
ANNUAL O&M COST								$24,301.06		
TOTAL NET PRESENT VALUE OF O & M										$373,555.89
SUBTOTAL COST										$4,030,402.45
CONTINGENCY (20%)										$806,080.49
TOTAL PRESENT VALUE COST FOR ALTERNATIVE S/W–3, OPTION C (without stone revetment)										$4,836,482.94

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ALTERNATIVE GW–2, OPTION A
LONG – TERM MONITORING
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
OPERATION AND MAINTENANCE COSTS										
Ground Water and Surface Water/Sediment Monitoring (including trip blanks, field blanks and duplicate samples)										
– Sampling	42	samples	$300.00	1994	5	1.000	$300.00	$12,600.00	30	$193,687.20
– Analysis:										
Full TCL/TAL	42	samples	$1,630.00	1993	10	1.031	$1,680.53	$70,582.26	30	$1,084,990.50
– Report Preparation	1	each	$14,000.00	1994	5	1.000	$14,000.00	$14,000.00	30	$215,208.00
ANNUAL O & M COST								$97,182.26		
TOTAL NET PRESENT VALUE OF O & M										$1,493,885.70
SUBTOTAL COST										$1,493,885.70
CONTINGENCY (20%)										$298,777.14
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW–2, OPTION A										$1,792,662.84

(1) – Calculated based on 5% interest rate.

ALTERNATIVE GW-3, OPTION B
SHEET PILING VERTICAL BARRIER
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
<u>CAPITAL COST – DIRECT</u>										
Sheet Piling Wall Construction										
(3,700 ft x 60 ft)										
–Mob/Demob	1	time	$15,100.00	1994	2	1.000	$15,100.00	$15,100.00		
–Steel Piles	222,000	v.l.f.	$13.70	1994	2	1.000	$13.70	$3,041,400.00		
–Health & Safety (17%)								$519,605.00		
Total Slurry Wall Construction Cost										$3,576,105.00
Observation Well Installation										
(20 45ft wells – 2")	20	each	$3,845.00	1992	6	1.077	$4,141.07	$82,821.30		
–Health & Safety (17%)					4			$14,079.62		
Total Observation Well Installation										$96,900.92
Equipment Decontamination										
–Rental of Steam Cleaner	8	months	$425.00	1994	2	1.000	$425.00	$3,400.00		
–Construction of Decon Pit										
Excavate Pit	15	cu. yd.	$3.82	1994	2	1.000	$3.82	$57.30		
Polyethylene Tarpulin	4,000	sq. ft.	$0.35	1994	2	1.000	$0.35	$1,400.00		
–Tanker Truck Rental	8	months	$650.00	1994	5	1.000	$650.00	$5,200.00		
–Disposal (Tanker Truck)	1	each	$1,600.00	1992	11	1.077	$1,723.20	$1,723.20		
Total Equipment Decontamination Cost										$11,780.50
Engineering Mgmt. Mob/Demob										
–Trailer	8	months	$450.00	1994	2	1.000	$450.00	$3,600.00		$3,600.00
Direct Capital Cost Subtotal										$3,688,386.42
<u>CAPITAL COST – INDIRECT</u>										
Engineering and Design (15 %)								$553,257.96		
Legal and Administrative (5%)								$184,419.32		
Total Indirect Capital Cost										$737,677.28
TOTAL CAPITAL COSTS										$4,426,063.71
<u>OPERATION AND MAINTENANCE COSTS</u>										
Sheet Pile and Observation Well										
–Annual Maintenance/Monitoring	200	hours	$100.00	1994	5	1.000	$100.00	$20,000.00	30	$307,440.00
ANNUAL O&M (1994 DOLLARS)								$20,000.00		
TOTAL NET PRESENT VALUE OF O&M										$307,440.00
SUBTOTAL COST										$4,733,503.71
CONTINGENCY (20%)										$946,700.74
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW-3, OPTION B										$5,680,204.45

(1) – Calculated based on 5% interest rate.

ALTERNATIVE GW-4, OPTION A - GROUND WATER EXTRACTION
SITE 09 - ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
<u>CAPITAL COST - DIRECT</u>										
Ground Water Extraction Wells										
- Mobilization	1	time	$1,000.00	1992	6	1.077	$1,077.00	$1,077.00		
- Well Construction and Materials										
(13 35-ft overburden wells - 4")	13	each	$4,860.00	1992	6	1.077	$5,234.22	$68,044.86		
(10 70-ft de p wells - 4")	10	each	$8,350.00	1992	6	1.077	$8,992.95	$89,929.50		
- Health and Safety (17%)					4			$11,567.63		
- Ground Water Extraction Pump	5	each	$300.00	1994	2	1.000	$300.00	$1,500.00		
Total Ground Water Treatment System Cost										$172,118.99
Piping From Extraction Wells to Treatment System										
- Trench Excavation & Backfill	2,400	l. ft.	$5.73	1994	2	1.000	$5.73	$13,752.00		
- 2" Diam. PVC in Trench	2,400	l. ft.	$4.60	1994	2	1.000	$4.60	$11,040.00		
- Pipe Bedding (sand)	2,400	l. ft.	$1.32	1994	2	1.000	$1.32	$3,168.00		
Total Piping Cost										$27,960.00
Direct Capital Cost Subtotal										$200,078.99
<u>CAPITAL COST - INDIRECT</u>										
Engineering and Design (10%)					1			$20,007.90		
Legal and Administrative (4%)					1			$8,003.16		
Total Indirect Capital Cost										$28,011.06
TOTAL CAPITAL COSTS										$228,090.04
<u>OPERATION AND MAINTENANCE COSTS</u>										
Extraction System O&M	1	ea	$22,000.00	1985	18	1.281	$28,182.00	$28,182.00	30	$433,213.70
ANNUAL O&M (1994$)								$28,182.00		
TOTAL NET PRESENT VALUE OF O&M										$433,213.70
SUBTOTAL										$661,303.75
CONTINGENCY (20%)										$132,260.75
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW-4, OPTION A										$793,564.50

(1) - Calculated based on 5% interest rate.

ALTERNATIVE GW–4, OPTION B
AIR STRIPPING
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST – DIRECT										
Air Stripping Treatment System										
– Air Stripper	1	each	$9,540.00	1992	19	1.077	$10,274.58	$10,274.58		
– Electrical Connections	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
– Equalization Tank	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
Total Air Stripping Treatment System Cost										$50,274.58
Direct Capital Cost Subtotal										$50,274.58
CAPITAL COST – INDIRECT										
Engineering and Design (10%)					1			$5,027.46		
Legal and Administrative (4%)					1			$2,010.98		
Total Indirect Capital Cost										$7,038.44
TOTAL CAPITAL COSTS										$57,313.02
OPERATION AND MAINTENANCE COSTS										
– Air Stripper O&M	1	year	$1,200.00	1992	19	1.077	$1,292.40	$1,292.40	30	$19,866.77
ANNUAL O&M (1994 $)								$1,292.40		
TOTAL NET PRESENT VALUE OF O&M										$19,866.77
SUBTOTAL										$77,179.79
CONTINGENCY (20%)										$15,435.96
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW–4, OPTION B										$92,615.75

(1) – Calculated based on 5% interest rate.

ALTERNATIVE GW-4, OPTION C
UV OXIDATION
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST – DIRECT										
UV Oxidation Treatment System										
– Site Preparation	1	LS.	$36,000.00	1990	22	1.135	$40,860.00	$40,860.00		
– UV Oxidation Unit	1	each	$85,000.00	1992	17	1.077	$91,545.00	$91,545.00		
– Bench Scale Testing and Reporting	1	each	$3,500.00	1992	17	1.077	$3,769.50	$3,769.50		
– Startup and Fixed Costs	1	LS.	$32,000.00	1990	22	1.135	$36,320.00	$36,320.00		
– Electrical Connection	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
– Equalization Tank	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
Total UV Oxidation Treatment System Cost										$212,494.50
Direct Capital Cost Subtotal										$212,494.50
CAPITAL COST – INDIRECT										
Engineering and Design (15%)					1			$31,874.18		
Legal and Administrative (5%)					1			$10,624.73		
Total Indirect Capital Cost										$42,498.90
TOTAL CAPITAL COSTS										$254,993.40
OPERATION AND MAINTENANCE COSTS										
– UV Oxidation O&M	1	year	$38,400.00	1992	17	1.077	$41,356.80	$41,356.80	30	$635,736.73
– UV Oxidation Power Supply	1	year	$2,200.00	1992	17	1.077	$2,369.40	$2,369.40	30	$36,422.42
ANNUAL O&M (1994 $)								$43,726.20		
TOTAL NET PRESENT VALUE OF O&M										$672,159.15
SUBTOTAL										$927,152.55
CONTINGENCY (20%)										$185,430.51
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW-4, OPTION C										$1,112,583.06

(1) – Calculated based on 5% interest rate.

ALTERNATIVE GW–4, OPTION D
CHEMICAL PRECIPITATION
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST – DIRECT										
Precipitation Treatment System										
– Neutralization/Precipitation/ Filtration/Filter Press Unit	1	each	$89,400.00	1987	9	1.219	$108,978.60	$108,978.60		
– Electrical Connections	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
– Equalization Tank	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
Total Ground Water Treatment System Cost										$148,978.60
Direct Capital Cost Subtotal										$148,978.60
CAPITAL COST – INDIRECT										
Engineering and Design (15%)					1			$22,346.79		
Legal and Administrative (5%)					1			$7,448.93		
Total Indirect Capital Cost										$29,795.72
TOTAL CAPITAL COSTS										$178,774.32
OPERATION AND MAINTENANCE COSTS										
– Precipitation O&M	1	year	$34,000.00	1987	9	1.219	$41,446.00	$41,446.00	30	$637,107.91
– Chemical Cost	1	year	$4,400.00	1987	9	1.219	$5,363.60	$5,363.60	30	$82,449.26
– Precipitate Transportation & Disposal	3.4	tons	$225.00	1994	5	1.000	$225.00	$765.00	30	$11,759.58
ANNUAL O&M (1994 $)								$47,574.60		
TOTAL NET PRESENT VALUE OF O&M										$731,316.75
SUBTOTAL										$910,091.07
CONTINGENCY (20%)										$182,018.21
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW–4, OPTION D										$1,092,109.29

(1) – Calculated based on 5% interest rate.

ALTERNATIVE GW−4, OPTION E
MEMBRANE MICROFILTRATION
SITE 09 − ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST − DIRECT										
Membrane Microfiltration Treatment System										
− Membrane Microfiltration Unit (includes capital, startup, & mob)	1	each	$311,800.00	1990	15	1.135	$353,893.00	$353,893.00		
− Equalization Tank	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
Total Membrane Microfiltration Treatment System Cost										$373,893.00
Direct Capital Cost Subtotal										$373,893.00
CAPITAL COST − INDIRECT										
Engineering and Design (15%)					1			$56,083.95		
Legal and Administrative (5%)					1			$18,694.65		
Total Indirect Capital Cost										$74,778.60
TOTAL CAPITAL COSTS										$448,671.60
OPERATION AND MAINTENANCE COSTS										
− Membrane Microfiltration O&M	1	year	$435,900.00	1990	15	1.135	$494,746.50	$494,746.50	30	$7,605,243.20
− Filter Cake Disposal	1	year	$55,200.00	1992	14	1.077	$59,450.40	$59,450.40	30	$913,871.55
ANNUAL O&M (1994 $)								$554,196.90		
TOTAL NET PRESENT VALUE OF O&M										$8,519,114.75
SUBTOTAL										$8,967,786.35
CONTINGENCY (20%)										$1,793,557.27
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW−4, OPTION E										$10,761,343.62

(1) − Calculated based on 5% interest rate.

ALTERNATIVE GW-4, OPTION F
DISCHARGE TO SURFACE WATER
SITE 09 - ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT										
Piping From Treatment System To Surface Water										
- Trench Excavation & Backfill	500	l. ft.	$5.73	1994	2	1.000	$5.73	$2,865.00		
- 2" Diam. PVC in Trench	500	l. ft.	$4.60	1994	2	1.000	$4.60	$2,300.00		
- Pipe Bedding (sand)	500	l. ft.	$1.32	1994	2	1.000	$1.32	$660.00		
Total Piping Cost										$5,825.00
Direct Capital Cost Subtotal										$5,825.00
CAPITAL COST - INDIRECT										
Engineering and Design (10%)					1			$582.50		
Legal and Administrative (4%)					1			$291.25		
Total Indirect Capital Cost										$873.75
TOTAL CAPITAL COSTS										$6,698.75
OPERATION AND MAINTENANCE COSTS										
Discharge Sampling & Analysis										
- Monthly Sampling	12	samples	$300.00	1994	5	1.000	$300.00	$3,600.00	30	$55,339.20
- Full TCL/TAL Analysis	12	samples	$1,630.00	1993	10	1.031	$1,680.53	$20,166.36	30	$309,997.29
ANNUAL O&M (1994 $)								$23,766.36		
TOTAL NET PRESENT VALUE OF O&M										$365,336.49
SUBTOTAL										$372,035.24
CONTINGENCY (20%)										$74,407.05
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW-4, OPTION F										$446,442.28

(1) - Calculated based on 5% interest rate.

ALTERNATIVE SD-2
LIMITED ACTION
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
TOTAL CAPITAL COSTS										$0.00
OPERATION AND MAINTENANCE COSTS										
Sediment Monitoring										
– Collection and Reporting	1	lump sum	$10,000.00	1994	5	1.000	$10,000.00	$10,000.00	30	$153,720.00
– Sample Collection	10	samples	$300.00	1994	5	1.000	$300.00	$3,000.00	30	$46,116.00
– Sample Analysis	10	each	$1,630.00	1993	10	1.031	$1,680.53	$16,805.30	30	$258,331.07
ANNUAL O & M COST								$29,805.30		
TOTAL NET PRESENT VALUE OF O & M										$458,167.07
SUBTOTAL COST										$458,167.07
CONTINGENCY (20%)										$91,633.41
TOTAL PRESENT VALUE COST FOR ALTERNATIVE SD-2										$549,800.49

(1) – Calculated based on 5% interest rate.

ALTERNATIVE SD-3
CONTAINMENT
SITE 09 – ALLEN HARBOR LANDFILL

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST – DIRECT										
Surface Controls										
– Stone Revetment	5,535	sq. yd.	$58.00	1994	2	1.000	$58.00	$321,030.00		
– Health & Safety (17%)								$54,575.10		
Total Surface Controls										$375,605.10
Equipment Decontamination										
– Rental of Steam Cleaner	2	months	$425.00	1994	2	1.000	$425.00	$850.00		
– Construction of Decon Pit										
Excavate Pit	15	cu. yd.	$3.82	1994	2	1.000	$3.82	$57.30		
Polyethylene Tarpaulin	400	sq. ft.	$0.35	1994	2	1.000	$0.35	$140.00		
– Tanker Truck Rental	2	months	$650.00	1994	5	1.000	$650.00	$1,300.00		
– Disposal (Tanker Truck)	1	each	$1,600.00	1992	13	1.077	$1,723.20	$1,723.20		
Total Equipment Decontamination Cost										$4,070.50
Direct Capital Cost Subtotal										$379,675.60
CAPITAL COST – INDIRECT										
Engineering and Design (10%)					1			$37,967.56		
Legal and Administrative (4%)					1			$15,187.02		
Total Indirect Capital Cost										$53,154.58
TOTAL CAPITAL COSTS										$432,830.18
OPERATION AND MAINTENANCE COSTS										
Stone Revetment O & M										
– Stone Revetment Inspection and Repairs	1	each	$500.00	1988	7	1.188	$594.00	$594.00	30	$9,130.97
ANNUAL O&M COST								$594.00		
TOTAL NET PRESENT VALUE OF O & M										$9,130.97
SUBTOTAL COST										$441,961.15
CONTINGENCY (20%)										$88,392.23
TOTAL PRESENT VALUE COST FOR ALTERNATIVE SD-3										$530,353.38

(1) – Calculated based on 5% interest rate.

COST REFERENCES

1) Remedial Action Costing Procedures Manual; JRB Associates; October 1987.

2) Means Site Work & Landscape Cost Data; 1994.

3) Waste Age; March 1988.

4) Compendium of Costs of Remedial Technologies at Hazardous Waste Sites; Environmental Law Institute; October 1987. EPA/600/2-87/08.

5) TRC Environmental Corporation; 1994.

6) Empire Soils Investigations, Inc., Division of Huntingdon; January 1992.

7) Waste Alternatives; December 1988.

8) Em Tech Environmental Services, Inc.; November 1991.

9) Technical Resource Document; Treatment Technologies for Metals/Cyanide Containing Wastes, Alliance Technologies Corp.; December 1987.

10) Weston Analytical Laboratory; 1993.

11) DuPont Environmental Treatment Services; 1992.

12) TRC Environmental Corporation; May 1993.

13) Calgon Corporation; 1992.

14) American Waste Services; September 16, 1992.

15) U.S. EPA Superfund Innovative Technology Evaluation, E.I. DuPont De Nemours & Company/Oberlin Filter Company Microfiltration Technology, Application Analysis Report; October 1991. EPA/540/A5-90/007.

16) TRC Environmental Corporation; September 1992.

17) Peroxidation Systems, Inc.; December 1992.

18) Remedial Action at Waste Disposal Sites; October 1985. EPA/625/6-85/006.

19) ORS Environmental; 1992.

20) Underground Storage Tank Corrective Action Technologies; January 1987. EPA/625/687/015.

21) Gundle Lining Systems; 1994.

22) USEPA, 1990. Ultrox International Ultraviolet Radiation/Oxidation Technology Applications Analysis Report; September 1990.

APPENDIX F
GROUND WATER MODELING INFORMATION

INTRODUCTION

For Alternative GW-4A - Ground Water Extraction Option, several ground water extraction options were evaluated using the computer ground water flow model MODFLOW (McDonald and Harbaugh, 1988). These evaluations were conducted with the goal of locating shallow and deep aquifer-screened extraction wells and adjusting extraction rates such that ground water contaminated at levels exceeding AWQC at Site 09 could be captured and extracted for treatment within an on-site ground water treatment facility.

Specifically, the goals of the remedial design modeling were to 1) accurately simulate the shallow and deep ground water flow regimes at Allen Harbor Landfill, and 2) optimize the design of a shallow and deep ground water extraction system to arrive at an optimal configuration and number of shallow and deep aquifer-screened extraction wells. The extraction simulations were conducted with the intent of dewatering the landfill's top fill layer and capturing and extracting the on-site ground water from the deep aquifer.

INITIAL MODEL SETUP

The area encompassed by the MODFLOW model grid is shown in Figure F-1. The grid was configured with the principal axes oriented to parallel the average direction of the deep aquifer ground water flow at Site 09 (northwest to southeast). The grid is comprised of 29 rows and 17 columns with a 50-foot uniform nodal spacing; the grid thus measures 1,450 feet by 850 feet, for a total simulation area of 1,232,500 square feet (28.3 acres). The nodal spacing was considered to be optimal to provide coverage of the large modeled area while also allowing flexibility in the development and optimization of the various extraction scenarios for the purpose of the Detailed Analysis of Alternatives.

Two-layer simulations were used to represent the shallow (Layer 1) and deep (Layer 2) aquifers. The shallow aquifer was assumed to be comprised of the fill layer and the sand and silt unit directly underlying the fill. The approximately 41-foot basal silt layer immediately overlying the bedrock at the site was considered to comprise the deep aquifer. Layer 1 was simulated as unconfined and Layer 2 was simulated as semi-confined, with the interlayer vertical leakance estimated at 1E-4 1/d. Shallow aquifer water level fluctuations will increase or decrease the shallow aquifer saturated thickness, and hence the transmissivity. Accordingly, the shallow aquifer transmissivity was input as the product of the aquifer saturated thickness (the hydraulic head minus the elevation of the aquifer bottom) and the hydraulic conductivity (K-value). For the deep aquifer, where the transmissivity remains constant with time as long as the aquifer is not dewatered, the transmissivity was entered as a single value. The initial input shallow aquifer nodal K-value was 6.5 ft/d; the initial input deep aquifer nodal transmissivity was 41 ft^2/d, or 1.0 ft/d (K) x 41 feet (b). These K-values were derived from the results of the Phase II RI shallow and deep monitoring well slug tests (Phase II RI Report, TRC, 1992), for those wells installed within the actual landfill area.

The model boundaries were extended outward as far as considered practical when taking into account the areal range of shallow and deep aquifer water level data points available. As the modeled area of the aquifers is not bounded on any side by an impermeable boundary, constant-head boundaries were placed at the edges of the modeled area to establish flow through the model for the model calibration. The potential constant head boundary effects from the model's domain boundaries are considered to be minimal and conservative. For all simulations where the site would be in direct contact with Allen Harbor, the nodes representing the shoreline were made constant-head boundaries with an assigned hydraulic head of 0 ft msl.

Model data sheets are provided following this summary and the associated figures. The MODFLOW output item "drawdown" is included in the model output regardless of whether or not a source or sink is simulated in the model. In the case of the steady-state calibration, the term quantifies only the change in hydraulic head between the initial input head value and the final equilibrium head calculated during the calibration. The head change closure criterion used for all simulations was 0.001 foot.

MODEL CALIBRATION

The model was calibrated to steady-state (non-stressed) conditions existing on August 13, 1993. For areal recharge, it was estimated that 45 percent of the 42.3 inches mean annual precipitation for the area infiltrates into the subsurface at the site to recharge the shallow ground water at a rate of 4.5E-3 ft/d. After each model run was conducted, the hydraulic head values at the constant-head nodes were adjusted as necessary until the model was calibrated to the steady-state conditions at the site on August 13, 1993. Figure F-2 shows the results of the steady-state calibration for the shallow and deep aquifers. The shallow aquifer K-values, deep aquifer transmissivity and interlayer vertical leakance were not adjusted.

REMEDIAL SIMULATIONS

Following the model calibration, four remedial simulations were run to evaluate the effects of installing an impermeable multi-layer cap atop the fill materials and/or extracting shallow and deep ground water via extraction wells and, for the extraction simulations, to establish the most favorable locations and pumping rates for the shallow and deep extraction wells. To establish the initial head conditions, the output shallow and deep head matrices from the model steady-state calibration were input as the initial shallow and deep aquifer hydraulic head matrices for the remedial simulations.

For the three simulations which included ground water extraction, capture zones were limited to those portions of the flow regime where the water table/piezometric surface could be seen to be sloped toward an extraction well, so that ground water, flowing perpendicular to the piezometric contours, would likely be drawn into the extraction well. Therefore, the extraction well zones of capture did not include the entire zone of influence for each well. For all simulations, 0.25 gpm was considered the extraction rate lower limit for effective capture. For the deep aquifer, 1.0 gpm was considered the maximum sustainable pumping rate at each extraction well. This estimate was derived from the results of the Phase II monitoring well development, when withdrawal rates greater than 1.0 gpm were seldom attainable at the deep monitoring wells, screened in the basal silt layer. In Table F-1, the results of the modeled remedial simulations are summarized in terms of the number of shallow and deep extraction wells required, the total shallow and deep system flows, and the total combined flow.

Simulation 1 - Impermeable Multi-Layer Cap Over Landfill

For Simulation 1, the effects of installing an impermeable multi-layer cap atop the landfill were modeled. The areal recharge to the model was removed, and the model was run for steady-state conditions. The model results, as shown in Figure F-3, indicate that the shallow aquifer water levels would recede, but subsurface recharge from the west and northwest would continue, resulting in continued shallow ground water flow southward through the landfill. The rate and direction of flow would be governed by the relative heads of the landward recharge areas and the Allen Harbor tidal water levels. The model indicated that the cap installation would have little to no impact upon the deep aquifer ground water flow at the site.

Simulation 2 - Impermeable Multi-Layer Cap Over Landfill, Shallow and Deep Aquifer Ground Water Extraction

For Simulation 2, in addition to an impermeable cap, shallow and deep aquifer extraction was simulated to evaluate the number, spacing and pumping rates of extraction wells required for the control and capture of the site shallow and deep ground water. All of the extraction simulations were conducted with the intent of dewatering the landfill's top fill layer and capturing and extracting the on-site ground water from the deep aquifer.

The results of Simulation 2 are shown in Figure F-4. For both the shallow and deep aquifers, a well spacing of 200 feet was necessary to provide for a sufficient density of wells for extraction to be sustainable. Even taking into account the substantial recharge that could be expected from Allen Harbor, the thin, silty shallow aquifer would have to be dewatered using closely-spaced wells with very low pumping rates and, as mentioned above, the deep silt aquifer can be expected to yield sustainable flows of only about 1 gpm. The model resulted in a configuration of 13 shallow extraction wells, with extraction rates ranging from 0.5 to 2.75 gpm, and 10 deep extraction wells pumping 1.0 gpm each. The total shallow extraction system flow would be 12.75 gpm, and the total deep system flow would be 10.0 gpm, for a total combined flow of 22.75 gpm for conveyance to an on-site treatment facility.

Simulation 3 - Impermeable Multi-Layer Cap Over Landfill, Sheet Piling Installed Along Sanford Road to Top of Silt Layer, Shallow and Deep Aquifer Ground Water Extraction

For Simulation 3, in addition to an impermeable cap and shallow and deep aquifer extraction, the installation of sheet piling along the eastern side of Sanford Road was modeled to evaluate its effect on the configuration of the proposed shallow and deep ground water extraction systems. It was assumed for the model that the sheet piling would be installed into the basal silt layer, so that the shallow aquifer would be completely penetrated by the barrier along Sanford Road. The impermeable boundary created by the sheet piling was simulated by the placement within the Layer 1 boundary array of a no-flow boundary along the northwestern edge of the model, along Sanford Road.

The results of Simulation 3 are presented in Figure F-5. A well spacing of 200 feet was again necessary to provide for a sufficient density of shallow and deep extraction wells for extraction to be sustainable. The principal effect of the sheet piling was to establish a barrier to the lateral subsurface recharge of the landfill's shallow ground water from the areas across Sanford Road to the west and northwest of the site. Some lateral subsurface recharge to the landfill could be expected from the north, between Sanford Road and Allen Harbor near 09-MW11S. In addition, recharge from Allen Harbor would continue to impact the site ground water. Although the number of shallow extraction wells would not be increased, the shallow aquifer would be dewatered using lower pumping rates than those necessary in Simulation 2, in the absence of the sheet piling. The deep silt aquifer did not show any impact due to the simulation of the sheet piling; it was not necessary to alter its 10-well, 10 gpm configuration. The model resulted in a configuration of 13 shallow extraction wells, with extraction rates ranging from 0.25 to 1.75 gpm, and 10 deep extraction wells pumping 1.0 gpm each. The total shallow extraction system flow would be 8.5 gpm, and the total deep system flow would be 10.0 gpm, for a total combined flow of 18.5 gpm for conveyance to an on-site treatment facility.

Simulation 4 - Impermeable Multi-Layer Cap Over Landfill, Sheet Piling Installed Surrounding Entire Landfill to Top of Silt Layer, Shallow and Deep Aquifer Ground Water Extraction

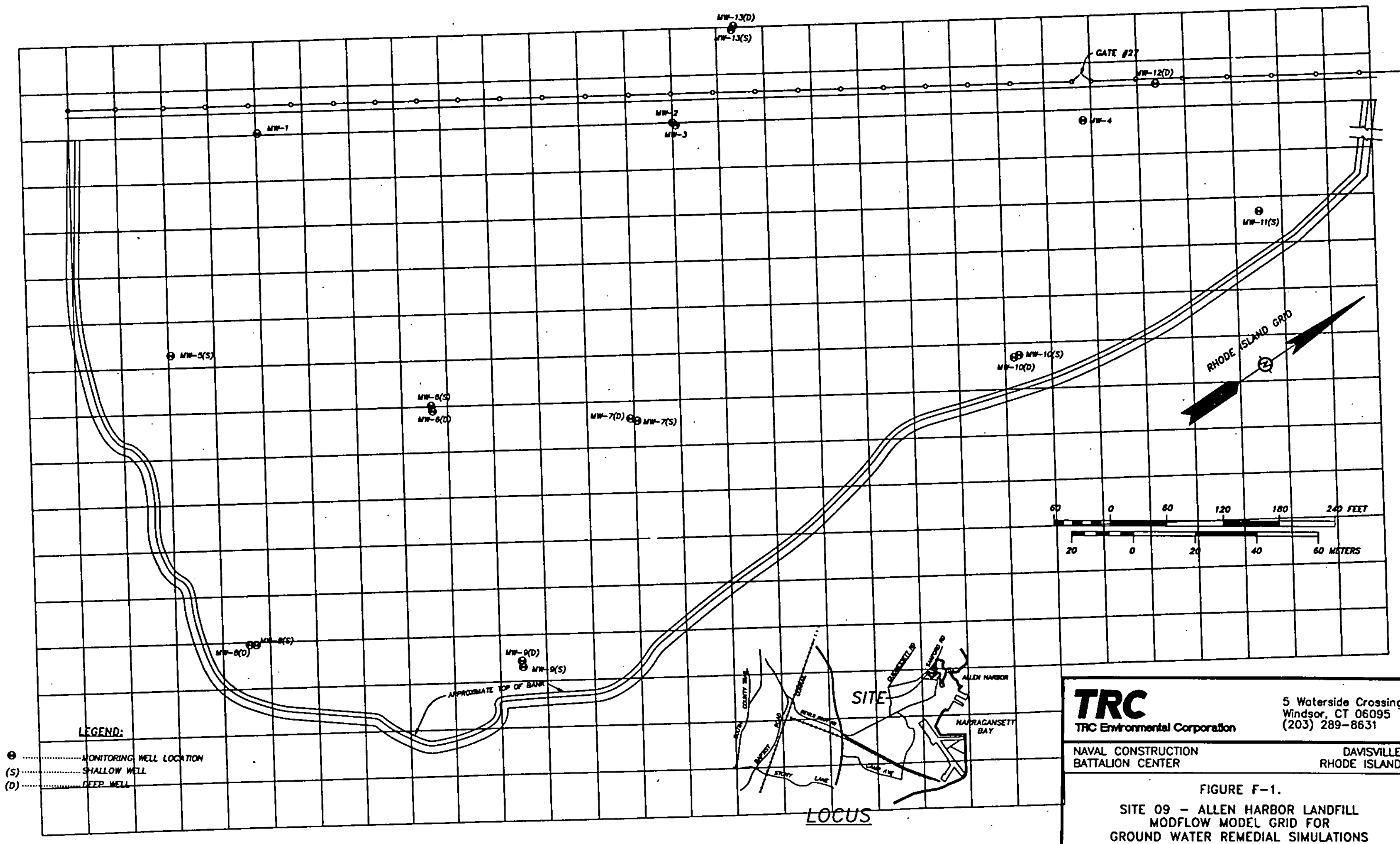
For Simulation 4, in addition to an impermeable cap and shallow and deep aquifer extraction, the installation of sheet piling around the entire landfill was modeled to evaluate its impact on the configuration of the proposed shallow and deep ground water extraction systems. As for Simulation 3, it was assumed for the model that the sheet piling would be installed into the basal silt layer, completely penetrating the shallow aquifer immediately surrounding the landfill. The sheet piling would thus effectively seal off the shallow aquifer at the Site 09 landfill from lateral subsurface recharge. The impermeable boundary created by the sheet piling was simulated by the placement within the Layer 1 boundary array of a no-flow boundary surrounding the entire landfill, including its shoreline.

The results of Simulation 4 are shown in Figure F-6. A well spacing of 200 feet was again necessary to provide for a sufficient density of shallow and deep extraction wells for shallow dewatering to be complete and deep extraction to be sustainable. The principal effect of the sheet piling was to establish a barrier to the lateral subsurface recharge of the landfill's shallow ground water from all directions, including Allen Harbor. Simulation 4 indicated that, using 13 shallow extraction wells, the shallow aquifer would be dewatered in approximately one year after the startup of the shallow aquifer extraction system. Once the shallow aquifer is dewatered, the need for shallow aquifer extraction should be intermittent due to the presence of the cap, sheet piling and deep aquifer extraction. The deep silt aquifer again did not show any impact due to the simulation of the sheet piling; it was not necessary to alter its 10-well, 10 gpm configuration. The model resulted in a configuration of 13 shallow extraction wells, with extraction rates ranging from 0.5 to 1.0 gpm, and 10 deep extraction wells pumping 1.0 gpm each. The total shallow extraction system flow would be 8.25 gpm while in operation, and the total deep system flow would be 10.0 gpm, for a total combined flow of 18.25 gpm for conveyance to an on-site treatment facility during shallow aquifer dewatering. After dewatering, the total flow to a treatment facility would be comprised of the 10 gpm from the deep extraction system. The sheet piling should not be expected to be absolutely impermeable; the shallow aquifer may require occasional extraction after the initial dewatering.

TABLE F-1
SUMMARY AND RESULTS OF MODELED REMEDIAL SIMULATIONS
FEASIBILITY STUDY
SITE 09 – ALLEN HARBOR LANDFILL
NCBC DAVISVILLE

SIMULATION	DESCRIPTION	NUMBER OF SHALLOW EXTRACTION WELLS	NUMBER OF DEEP EXTRACTION WELLS	TOTAL SHALLOW FLOW (GPM)	TOTAL DEEP FLOW (GPM)	TOTAL COMBINED FLOW (GPM)
1	IMPERMEABLE MULTI-LAYER CAP OVER LANDFILL	0	0	0	0	0
2	IMPERMEABLE MULTI-LAYER CAP OVER LANDFILL, SHALLOW AND DEEP AQUIFER GROUND WATER EXTRACTION	13	10	12.75	10.00	22.75
3	IMPERMEABLE MULTI-LAYER CAP OVER LANDFILL, SHEET PILING INSTALLED ALONG SANFORD ROAD TO TOP OF SILT LAYER, SHALLOW AND DEEP AQUIFER GROUND WATER EXTRACTION	13	10	8.50	10.00	18.50
4	IMPERMEABLE MULTI-LAYER CAP OVER LANDFILL, SHEET PILING INSTALLED SURROUNDING ENTIRE LANDFILL TO TOP OF SILT LAYER, SHALLOW AQUIFER DEWATERING AND DEEP AQUIFER GROUND WATER EXTRACTION.	13	10	8.25*	10.00	18.25*

NOTES: * THE DEWATERING OF THE SHALLOW AQUIFER WAS MODELED TO OCCUR APPROXIMATELY ONE YEAR AFTER THE STARTUP OF THE SHALLOW AQUIFER EXTRACTION SYSTEM. AFTER ONE YEAR, THE NEED FOR SHALLOW AQUIFER EXTRACTION SHOULD BE INTERMITTENT DUE TO THE PRESENCE OF THE CAP, SHEET PILING AND DEEP AQUIFER EXTRACTION.



TRC
TRC Environmental Corporation

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Windsor, CT 06095
(203) 289-8631

NAVAL CONSTRUCTION BATTALION CENTER — DAVISVILLE RHODE ISLAND

FIGURE F-1.
SITE 09 – ALLEN HARBOR LANDFILL
MODFLOW MODEL GRID FOR
GROUND WATER REMEDIAL SIMULATIONS

Date: 3/94 | Project No. 01042-0040

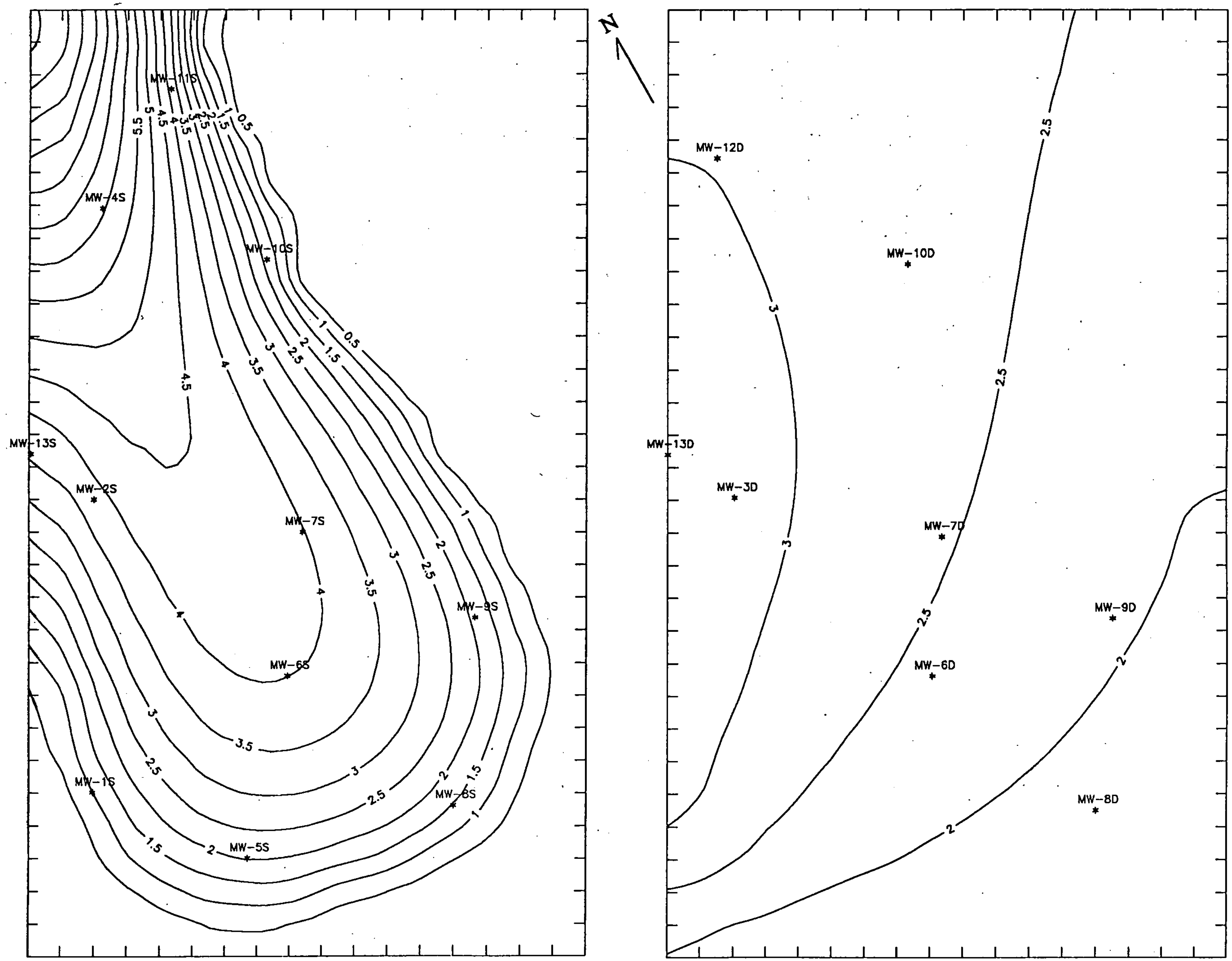

FIGURE F-2. RESULTS OF GROUND WATER FLOW MODEL CALIBRATION TO STEADY-STATE CONDITIONS ON AUGUST 13, 1993, SHALLOW AND DEEP AQUIFERS

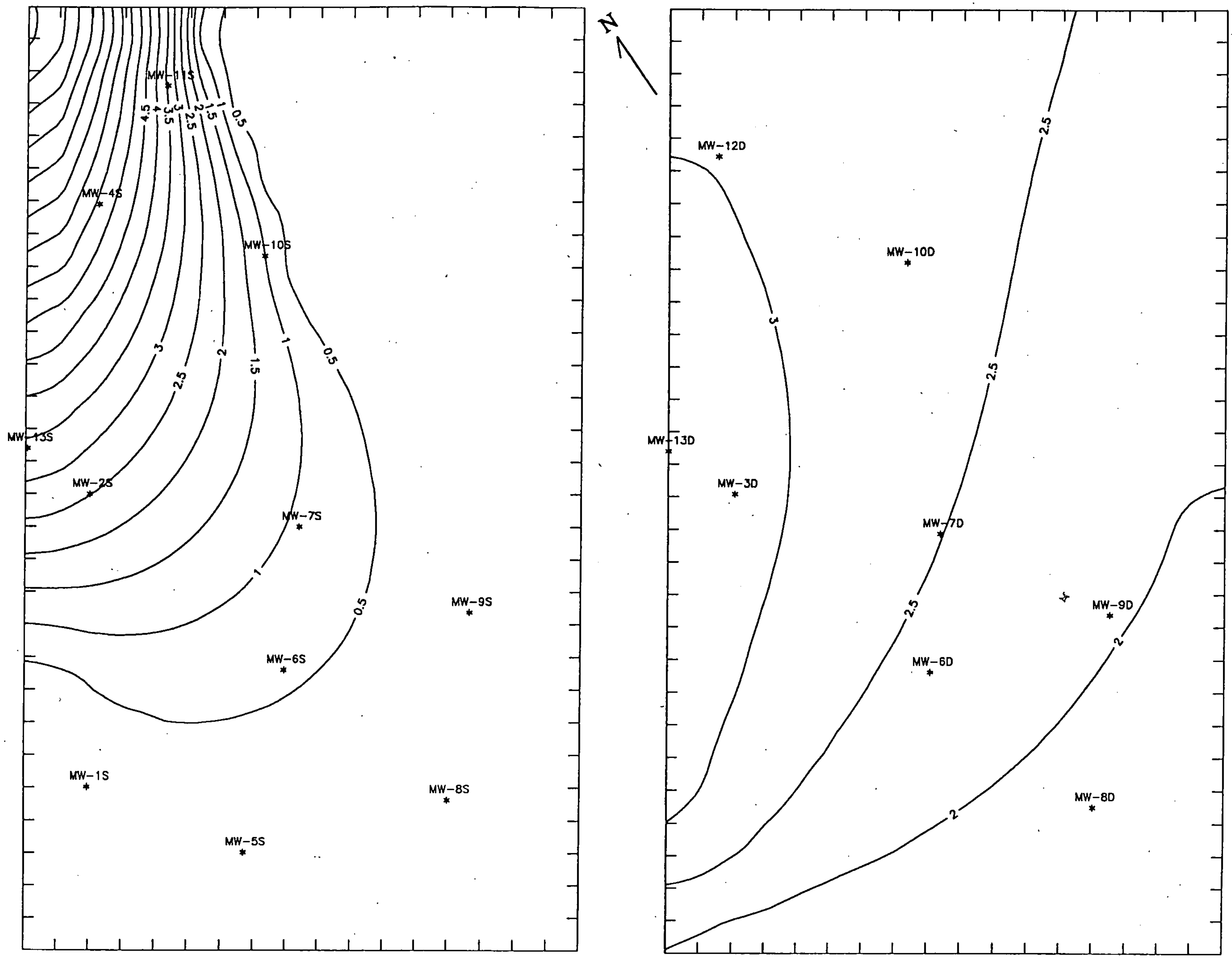

FIGURE F-3. RESULTS OF SIMULATION 1, SHALLOW AND DEEP AQUIFERS

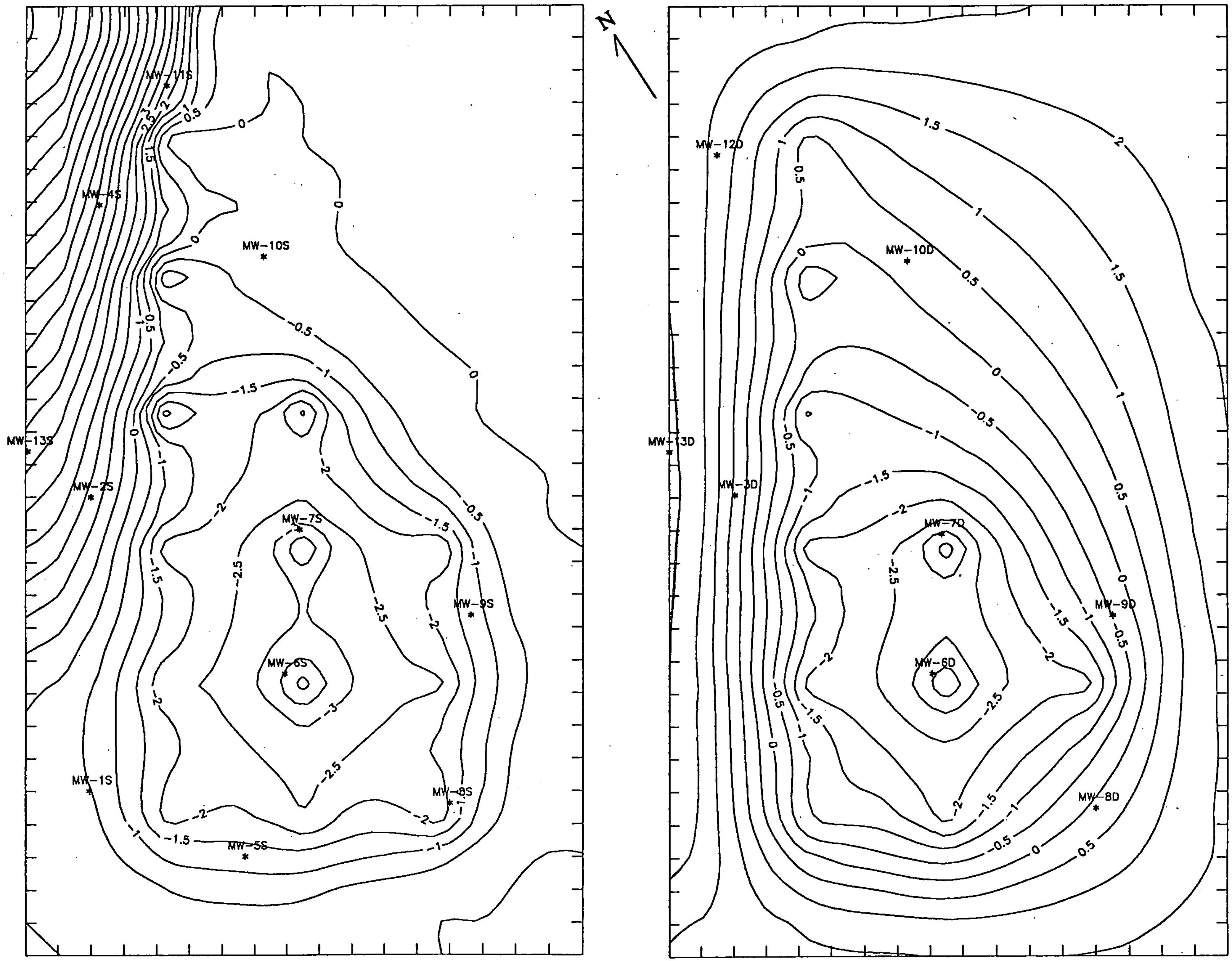

FIGURE F-4. RESULTS OF SIMULATION 2, SHALLOW AND DEEP AQUIFERS

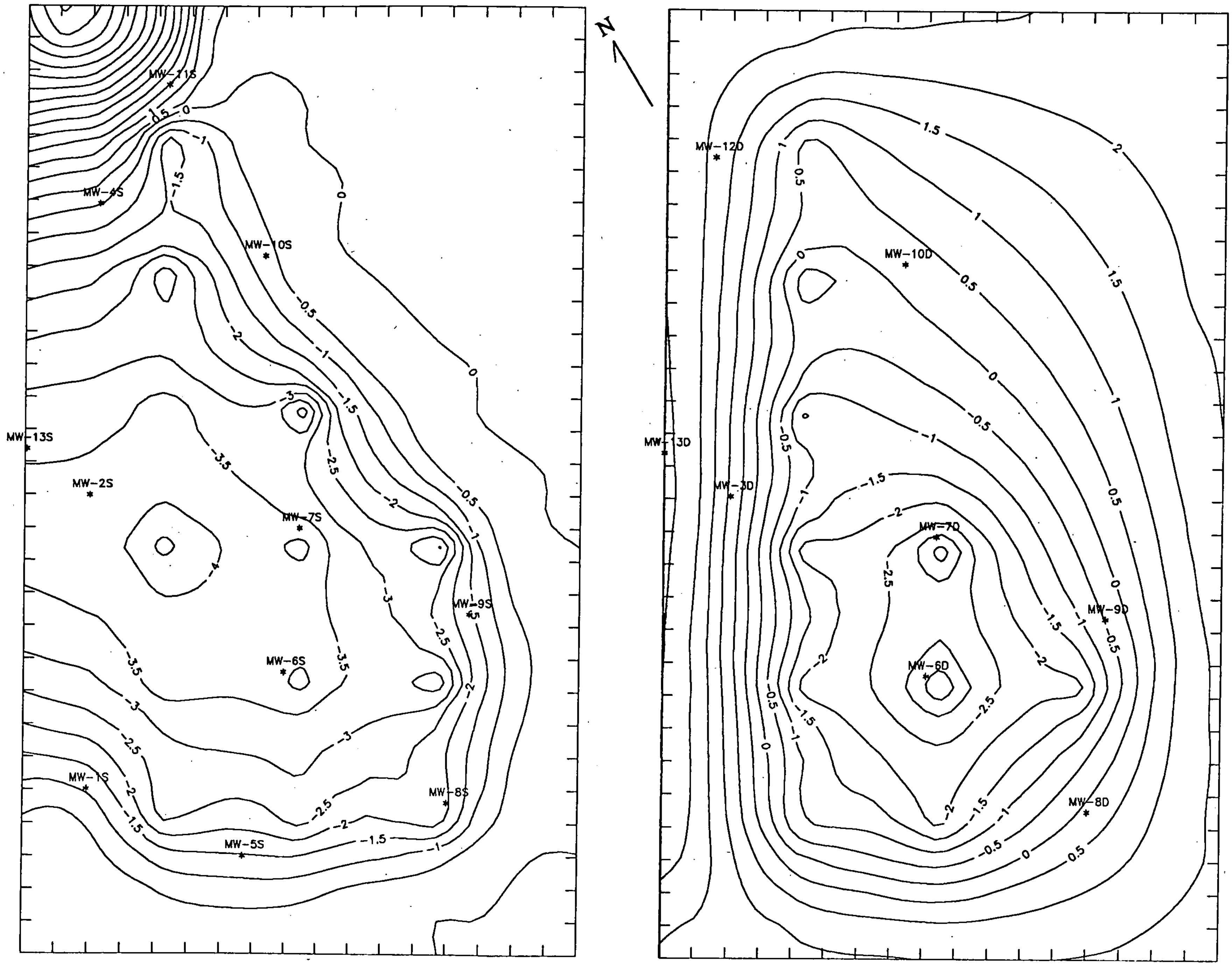

FIGURE F-5. RESULTS OF SIMULATION 3, SHALLOW AND DEEP AQUIFERS

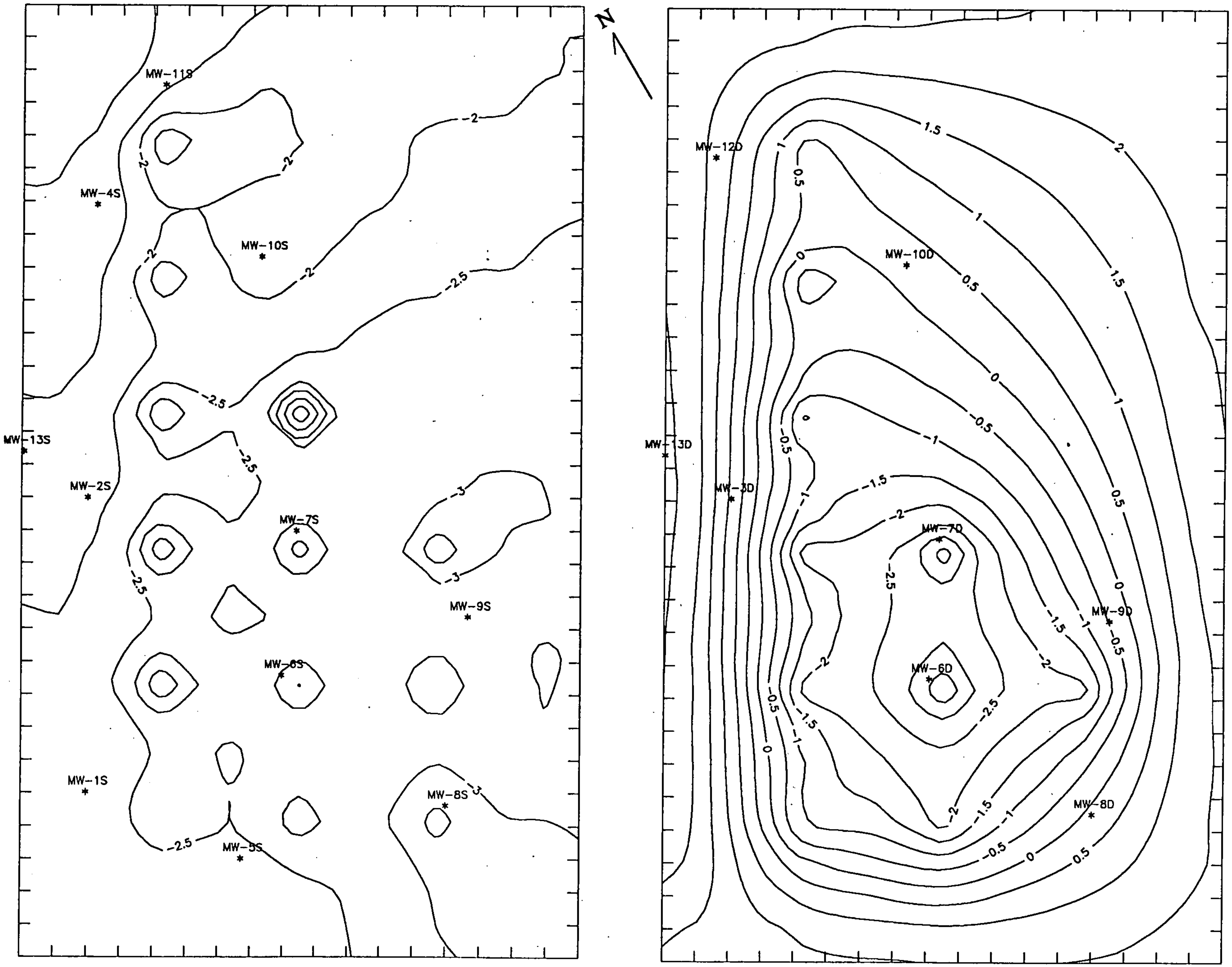

FIGURE F-6. RESULTS OF SIMULATION 4, SHALLOW AND DEEP AQUIFERS

1 U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
0NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY STEADY-STATE CALIBRATION TO CONDITIONS 08/13/93
2 LAYERS 29 ROWS 17 COLUMNS
1 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS DAYS
0I/O UNITS:

ELEMENT OF IUNIT:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
I/O UNIT:	11	0	0	0	0	0	0	18	19	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0

0BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 1
ARRAYS RHS AND BUFF WILL SHARE MEMORY.
START HEAD WILL BE SAVED
9421 ELEMENTS IN X ARRAY ARE USED BY BAS
9421 ELEMENTS OF X ARRAY USED OUT OF 100000
0BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 11
STEADY-STATE SIMULATION

LAYER	AQUIFER TYPE
1	1
2	0

988 ELEMENTS IN X ARRAY ARE USED BY BCF
10409 ELEMENTS OF X ARRAY USED OUT OF 100000
0RCH1 -- RECHARGE PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 18
OPTION 1 -- RECHARGE TO TOP LAYER
493 ELEMENTS OF X ARRAY USED FOR RECHARGE
10902 ELEMENTS OF X ARRAY USED OUT OF 100000
0SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 19
MAXIMUM OF 50 ITERATIONS ALLOWED FOR CLOSURE
5 ITERATION PARAMETERS
4149 ELEMENTS IN X ARRAY ARE USED BY SIP
15051 ELEMENTS OF X ARRAY USED OUT OF 100000
1NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY STEADY-STATE CALIBRATION TO CONDITIONS 08/13/93
0

BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

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0 2	-1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

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0AQUIFER HEAD WILL BE SET TO 999.99 AT ALL NO-FLOW NODES (IBOUND=0).
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INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (17F4.1)

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	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
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	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
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	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 4	8.200	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
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	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 10	5.200	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 11	4.800	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 12	4.300	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 13	3.800	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 14	3.500	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 15	3.100	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 16	2.700	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 17	2.200	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 18	1.700	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 19	1.200	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 20	.7000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 21	.2000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 22	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 23	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 24	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 25	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 26	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 27	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 28	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
0 29	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000			

0

INITIAL HEAD FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (17F4.1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	2.900	2.900	2.800	2.800	2.800	2.700	2.700	2.700	2.600	2.600	2.600	2.500	2.500	2.500	2.400	2.400	2.400
0 2	2.900	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.400
0 3	2.900	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.300
0 4	2.900	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.300
0 5	3.000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.300
0 6	3.100	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.300
0 7	3.100	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.200
0 8	3.100	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.200
0 9	3.200	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.200
0 10	3.200	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.200
0 11	3.300	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.100
0 12	3.300	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.100
0 13	3.400	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.100
0 14	3.400	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.100
0 15	3.500	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.000
0 16	3.500	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.900
0 17	3.400	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.900
0 18	3.400	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.900
0 19	3.300	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.900
0 20	3.300	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.800
0 21	3.300	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.800
0 22	3.200	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.800
0 23	3.200	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.700
0 24	3.200	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.700
0 25	3.100	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.700
0 26	3.100	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.600
0 27	2.700	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.600
0 28	2.300	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.600
0 29	1.800	1.800	1.800	1.800	1.700	1.700	1.700	1.700	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600

```
OHEAD PRINT FORMAT IS FORMAT NUMBER   4    DRAWDOWN PRINT FORMAT IS FORMAT NUMBER   9
OHEADS WILL BE SAVED ON UNIT 30    DRAWDOWNS WILL BE SAVED ON UNIT 40
OOUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
0                                                    COLUMN TO ROW ANISOTROPY =   1.000000
0                                                                        DELR =   50.00000
0                                                                        DELC =   50.00000
0                                                       HYD. COND. ALONG ROWS =   6.500000     FOR LAYER  1
0                                                                      BOTTOM =  -6.900000     FOR LAYER  1
0                                                    VERT HYD COND /THICKNESS =   .1000000E-04 FOR LAYER  1
0                                                        TRANSMIS. ALONG ROWS =   41.00000     FOR LAYER  2
0


                                                         SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE
                                                         -------------------------------------------
0                                                MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =        50
                                                                 ACCELERATION PARAMETER =      1.0000
                                                     HEAD CHANGE CRITERION FOR CLOSURE =      .10000E-02
                                                     SIP HEAD CHANGE PRINTOUT INTERVAL =         1
0                                                    CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED
1                                                   STRESS PERIOD NO.    1, LENGTH =    1825.000
                                                    ----------------------------------------------

                                                    NUMBER OF TIME STEPS =      1

                                                     MULTIPLIER FOR DELT =      1.000

                                                  INITIAL TIME STEP SIZE =   1825.000
```

```
0                                                                              RECHARGE =    .4500000E-02
0AVERAGE SEED =  .00036169
 MINIMUM SEED =  .00024698
0
    5 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

             .0000000E+00   .8620942E+00   .9809819E+00   .9973773E+00   .9996383E+00
0
    14 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD  1
0MAXIMUM HEAD CHANGE FOR EACH ITERATION:
0 HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL
 ------------------------------------------------------------------------------------------------------------------------------------
    7.730     (  1,  2,  2)   2.820      (  1,  5,  3)   2.893      (  1, 14,  7)   1.012      (  2, 12,  9)  -.5421      (  1, 13,  9)
   .9702E-01 (  1, 11,  8)   .1723      (  1, 13,  9)   .5907E-01 (  1, 14,  6)   .5881E-01 (  1, 17,  9)  -.1842E-01 (  1, 16,  8)
  -.2078E-02 (  1, 18, 10)  -.2626E-02 (  2,  7, 11)  -.5245E-02 (  1, 16,  9)  -.9056E-03 (  1, 23,  6)
0
0HEAD/DRAWDOWN PRINTOUT FLAG = 1     TOTAL BUDGET PRINTOUT FLAG = 1     CELL-BY-CELL FLOW TERM FLAG = 0
0OUTPUT FLAGS FOR EACH LAYER:
           HEAD    DRAWDOWN  HEAD  DRAWDOWN
 LAYER  PRINTOUT  PRINTOUT  SAVE    SAVE
 ----------------------------------------
    1        1         1       1      1
    2        1         1       1      1
1                              HEAD IN LAYER  1 AT END OF TIME STEP  1 IN STRESS PERIOD  1
                 ---------------------------------------------------------------------------
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	10.00	8.50	7.00	5.00	3.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	9.30	8.17	6.85	5.24	3.37	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 3	8.70	7.80	6.69	5.35	3.75	1.73	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 4	8.20	7.45	6.52	5.39	4.04	2.35	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 5	7.70	7.10	6.34	5.40	4.28	2.93	1.37	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 6	7.20	6.74	6.14	5.37	4.44	3.31	1.93	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 7	6.70	6.39	5.92	5.31	4.54	3.60	2.47	1.14	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 8	6.20	6.02	5.70	5.23	4.60	3.81	2.82	1.59	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 9	5.70	5.66	5.47	5.13	4.63	3.97	3.11	1.93	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 10	5.20	5.31	5.24	5.02	4.65	4.12	3.42	2.49	1.29	.00	.00	.00	.00	.00	.00	.00	.00
0 11	4.80	4.98	5.01	4.90	4.65	4.25	3.70	2.99	2.12	1.14	.00	.00	.00	.00	.00	.00	.00
0 12	4.30	4.63	4.78	4.78	4.64	4.36	3.94	3.40	2.72	1.94	1.03	.00	.00	.00	.00	.00	.00
0 13	3.80	4.29	4.56	4.65	4.61	4.43	4.13	3.71	3.17	2.52	1.76	.88	.00	.00	.00	.00	.00
0 14	3.50	4.00	4.34	4.52	4.56	4.47	4.26	3.94	3.50	2.96	2.27	1.38	.00	.00	.00	.00	.00
0 15	3.10	3.70	4.11	4.37	4.49	4.48	4.35	4.11	3.76	3.29	2.70	1.96	1.01	.00	.00	.00	.00
0 16	2.70	3.38	3.87	4.20	4.39	4.45	4.39	4.22	3.94	3.55	3.05	2.42	1.66	.82	.00	.00	.00
0 17	2.20	3.02	3.61	4.02	4.27	4.39	4.39	4.28	4.06	3.73	3.30	2.75	2.08	1.23	.00	.00	.00
0 18	1.70	2.65	3.33	3.81	4.13	4.30	4.35	4.29	4.12	3.85	3.47	2.99	2.39	1.66	.79	.00	.00
0 19	1.20	2.28	3.05	3.59	3.96	4.18	4.27	4.25	4.12	3.89	3.56	3.13	2.60	1.94	1.12	.00	.00
0 20	.70	1.91	2.76	3.35	3.76	4.02	4.14	4.15	4.06	3.87	3.58	3.19	2.70	2.11	1.41	.62	.00
0 21	.20	1.57	2.48	3.11	3.54	3.82	3.97	4.01	3.94	3.77	3.51	3.16	2.70	2.15	1.49	.76	.00
0 22	.00	1.31	2.21	2.85	3.30	3.59	3.76	3.81	3.76	3.61	3.36	3.03	2.59	2.05	1.39	.62	.00
0 23	.00	1.09	1.93	2.56	3.01	3.31	3.49	3.54	3.50	3.36	3.13	2.81	2.39	1.84	1.12	.00	.00
0 24	.00	.76	1.59	2.23	2.68	2.98	3.15	3.21	3.16	3.02	2.80	2.49	2.08	1.56	.90	.00	.00
0 25	.00	.00	1.15	1.84	2.29	2.58	2.75	2.79	2.73	2.58	2.35	2.04	1.64	1.18	.60	.00	.00
0 26	.00	.00	.84	1.42	1.84	2.11	2.25	2.28	2.19	2.00	1.77	1.45	1.01	.63	.00	.00	.00
0 27	.00	.00	.50	.88	1.28	1.54	1.65	1.65	1.50	1.22	1.00	.70	.00	.00	.00	.00	.00
0 28	.00	.00	.00	.00	.61	.85	.93	.89	.68	.00	.00	.00	.00	.00	.00	.00	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

```
1                              HEAD IN LAYER  2 AT END OF TIME STEP  1 IN STRESS PERIOD  1
                 ---------------------------------------------------------------------------
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	2.90	2.90	2.80	2.80	2.80	2.70	2.70	2.70	2.60	2.60	2.60	2.50	2.50	2.50	2.40	2.40	2.40
0 2	2.90	2.88	2.84	2.82	2.79	2.74	2.70	2.67	2.62	2.59	2.56	2.51	2.49	2.46	2.41	2.39	2.40
0 3	2.90	2.89	2.86	2.83	2.79	2.75	2.71	2.67	2.63	2.59	2.55	2.51	2.47	2.43	2.39	2.36	2.30
0 4	2.90	2.91	2.89	2.85	2.81	2.76	2.72	2.67	2.63	2.58	2.54	2.50	2.46	2.42	2.38	2.34	2.30
0 5	3.00	2.96	2.92	2.88	2.83	2.78	2.73	2.68	2.63	2.58	2.53	2.49	2.44	2.40	2.36	2.33	2.30
0 6	3.10	3.02	2.96	2.90	2.85	2.79	2.74	2.68	2.63	2.58	2.53	2.48	2.43	2.39	2.35	2.31	2.30
0 7	3.10	3.04	2.98	2.93	2.87	2.81	2.74	2.69	2.63	2.57	2.52	2.47	2.42	2.37	2.32	2.27	2.20
0 8	3.10	3.07	3.01	2.95	2.88	2.82	2.75	2.69	2.63	2.57	2.51	2.45	2.40	2.35	2.30	2.25	2.20
0 9	3.20	3.11	3.04	2.97	2.90	2.83	2.76	2.69	2.63	2.56	2.50	2.44	2.39	2.33	2.28	2.24	2.20
0 10	3.20	3.15	3.07	3.00	2.92	2.84	2.77	2.69	2.62	2.56	2.49	2.43	2.37	2.32	2.26	2.22	2.20
0 11	3.30	3.19	3.10	3.02	2.93	2.85	2.77	2.69	2.62	2.55	2.48	2.41	2.35	2.29	2.24	2.18	2.10
0 12	3.30	3.22	3.13	3.04	2.94	2.86	2.77	2.69	2.61	2.54	2.47	2.40	2.33	2.27	2.21	2.16	2.10
0 13	3.40	3.27	3.16	3.05	2.95	2.86	2.77	2.68	2.60	2.52	2.45	2.38	2.31	2.25	2.19	2.14	2.10
0 14	3.40	3.29	3.17	3.06	2.95	2.86	2.76	2.67	2.59	2.51	2.43	2.36	2.29	2.22	2.16	2.12	2.10
0 15	3.50	3.32	3.18	3.06	2.95	2.84	2.75	2.66	2.57	2.49	2.41	2.33	2.26	2.19	2.13	2.06	2.00
0 16	3.50	3.32	3.18	3.05	2.93	2.83	2.73	2.63	2.55	2.46	2.38	2.30	2.23	2.16	2.09	2.01	1.90
0 17	3.40	3.28	3.15	3.03	2.91	2.80	2.70	2.61	2.52	2.43	2.35	2.27	2.20	2.13	2.05	1.98	1.90
0 18	3.40	3.25	3.12	2.99	2.88	2.77	2.67	2.57	2.48	2.40	2.32	2.24	2.16	2.09	2.02	1.96	1.90
0 19	3.30	3.20	3.08	2.95	2.84	2.73	2.63	2.53	2.44	2.36	2.28	2.20	2.13	2.06	1.99	1.93	1.90
0 20	3.30	3.17	3.03	2.91	2.79	2.68	2.58	2.48	2.39	2.31	2.23	2.16	2.09	2.02	1.95	1.89	1.80
0 21	3.30	3.13	2.99	2.86	2.74	2.62	2.52	2.43	2.34	2.26	2.18	2.11	2.04	1.98	1.92	1.86	1.80
0 22	3.20	3.07	2.93	2.79	2.67	2.56	2.46	2.36	2.28	2.20	2.13	2.06	2.00	1.94	1.88	1.83	1.80
0 23	3.20	3.03	2.87	2.72	2.59	2.48	2.38	2.29	2.21	2.14	2.07	2.01	1.95	1.89	1.83	1.78	1.70
0 24	3.20	2.97	2.79	2.63	2.50	2.39	2.29	2.21	2.13	2.06	2.00	1.95	1.89	1.84	1.79	1.75	1.70
0 25	3.10	2.87	2.67	2.52	2.39	2.28	2.19	2.11	2.05	1.99	1.93	1.88	1.84	1.79	1.75	1.72	1.70
0 26	3.10	2.74	2.53	2.37	2.25	2.16	2.08	2.01	1.95	1.90	1.86	1.81	1.78	1.74	1.71	1.66	1.60
0 27	2.70	2.48	2.32	2.19	2.09	2.02	1.96	1.90	1.85	1.81	1.77	1.74	1.72	1.69	1.67	1.64	1.60
0 28	2.30	2.16	2.07	1.99	1.91	1.87	1.83	1.79	1.74	1.71	1.69	1.67	1.66	1.65	1.63	1.62	1.60
0 29	1.80	1.80	1.80	1.80	1.70	1.70	1.70	1.70	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60

0HEAD WILL BE SAVED ON UNIT 30 AT END OF TIME STEP 1, STRESS PERIOD 1

1 DRAWDOWN IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	.00	-8.17	-6.85	-5.24	-3.37	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 3	.00	-7.80	-6.69	-5.35	-3.75	-1.73	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 4	.00	-7.45	-6.52	-5.39	-4.04	-2.35	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 5	.00	-7.10	-6.34	-5.40	-4.28	-2.93	-1.37	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 6	.00	-6.74	-6.14	-5.37	-4.44	-3.31	-1.93	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 7	.00	-6.39	-5.92	-5.31	-4.54	-3.60	-2.47	-1.14	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 8	.00	-6.02	-5.70	-5.23	-4.60	-3.81	-2.82	-1.59	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 9	.00	-5.66	-5.47	-5.13	-4.63	-3.97	-3.11	-1.93	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 10	.00	-5.31	-5.24	-5.02	-4.65	-4.12	-3.42	-2.49	-1.29	.00	.00	.00	.00	.00	.00	.00	.00
0 11	.00	-4.98	-5.01	-4.90	-4.65	-4.25	-3.70	-2.99	-2.12	-1.14	.00	.00	.00	.00	.00	.00	.00
0 12	.00	-4.63	-4.78	-4.78	-4.64	-4.36	-3.94	-3.40	-2.72	-1.94	-1.03	.00	.00	.00	.00	.00	.00
0 13	.00	-4.29	-4.56	-4.65	-4.61	-4.43	-4.13	-3.71	-3.17	-2.52	-1.76	-.88	.00	.00	.00	.00	.00
0 14	.00	-4.00	-4.34	-4.52	-4.56	-4.47	-4.26	-3.94	-3.50	-2.96	-2.27	-1.38	.00	.00	.00	.00	.00
0 15	.00	-3.70	-4.11	-4.37	-4.49	-4.48	-4.35	-4.11	-3.76	-3.29	-2.70	-1.96	-1.01	.00	.00	.00	.00
0 16	.00	-3.38	-3.87	-4.20	-4.39	-4.45	-4.39	-4.22	-3.94	-3.55	-3.05	-2.42	-1.66	-.82	.00	.00	.00
0 17	.00	-3.02	-3.61	-4.02	-4.27	-4.39	-4.39	-4.28	-4.06	-3.73	-3.30	-2.75	-2.08	-1.23	.00	.00	.00
0 18	.00	-2.65	-3.33	-3.81	-4.13	-4.30	-4.35	-4.29	-4.12	-3.85	-3.47	-2.99	-2.39	-1.66	-.79	.00	.00
0 19	.00	-2.28	-3.05	-3.59	-3.96	-4.18	-4.27	-4.25	-4.12	-3.89	-3.56	-3.13	-2.60	-1.94	-1.12	.00	.00
0 20	.00	-1.91	-2.76	-3.35	-3.76	-4.02	-4.14	-4.15	-4.06	-3.87	-3.58	-3.19	-2.70	-2.11	-1.41	-.62	.00
0 21	.00	-1.57	-2.48	-3.11	-3.54	-3.82	-3.97	-4.01	-3.94	-3.77	-3.51	-3.16	-2.70	-2.15	-1.49	-.76	.00
0 22	.00	-1.31	-2.21	-2.85	-3.30	-3.59	-3.76	-3.81	-3.76	-3.61	-3.36	-3.03	-2.59	-2.05	-1.39	-.62	.00

0 23	.00	-1.09	-1.93	-2.56	-3.01	-3.31	-3.49	-3.54	-3.50	-3.36	-3.13	-2.81	-2.39	-1.84	-1.12	.00	.00
0 24	.00	-.76	-1.59	-2.23	-2.68	-2.98	-3.15	-3.21	-3.16	-3.02	-2.80	-2.49	-2.08	-1.56	-.90	.00	.00
0 25	.00	.00	-1.15	-1.84	-2.29	-2.58	-2.75	-2.79	-2.73	-2.58	-2.35	-2.04	-1.64	-1.18	-.60	.00	.00
0 26	.00	.00	-.84	-1.42	-1.84	-2.11	-2.25	-2.28	-2.19	-2.00	-1.77	-1.45	-1.01	-.63	.00	.00	.00
0 27	.00	.00	-.50	-.88	-1.28	-1.54	-1.65	-1.65	-1.50	-1.22	-1.00	-.70	.00	.00	.00	.00	.00
0 28	.00	.00	.00	.00	-.61	-.85	-.93	-.89	-.68	.00	.00	.00	.00	.00	.00	.00	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

1 DRAWDOWN IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	.00	-2.88	-2.84	-2.82	-2.79	-2.74	-2.70	-2.67	-2.62	-2.59	-2.56	-2.51	-2.49	-2.46	-2.41	-2.39	.00
0 3	.00	-2.89	-2.86	-2.83	-2.79	-2.75	-2.71	-2.67	-2.63	-2.59	-2.55	-2.51	-2.47	-2.43	-2.39	-2.36	.00
0 4	.00	-2.91	-2.89	-2.85	-2.81	-2.76	-2.72	-2.67	-2.63	-2.58	-2.54	-2.50	-2.46	-2.42	-2.38	-2.34	.00
0 5	.00	-2.96	-2.92	-2.88	-2.83	-2.78	-2.73	-2.68	-2.63	-2.58	-2.53	-2.49	-2.44	-2.40	-2.36	-2.33	.00
0 6	.00	-3.02	-2.96	-2.90	-2.85	-2.79	-2.74	-2.68	-2.63	-2.58	-2.53	-2.48	-2.43	-2.39	-2.35	-2.31	.00
0 7	.00	-3.04	-2.98	-2.93	-2.87	-2.81	-2.74	-2.69	-2.63	-2.57	-2.52	-2.47	-2.42	-2.37	-2.32	-2.27	.00
0 8	.00	-3.07	-3.01	-2.95	-2.88	-2.82	-2.75	-2.69	-2.63	-2.57	-2.51	-2.45	-2.40	-2.35	-2.30	-2.25	.00
0 9	.00	-3.11	-3.04	-2.97	-2.90	-2.83	-2.76	-2.69	-2.63	-2.56	-2.50	-2.44	-2.39	-2.33	-2.28	-2.24	.00
0 10	.00	-3.15	-3.07	-3.00	-2.92	-2.84	-2.77	-2.69	-2.62	-2.56	-2.49	-2.43	-2.37	-2.32	-2.26	-2.22	.00
0 11	.00	-3.19	-3.10	-3.02	-2.93	-2.85	-2.77	-2.69	-2.62	-2.55	-2.48	-2.41	-2.35	-2.29	-2.24	-2.18	.00
0 12	.00	-3.22	-3.13	-3.04	-2.94	-2.86	-2.77	-2.69	-2.61	-2.54	-2.47	-2.40	-2.33	-2.27	-2.21	-2.16	.00
0 13	.00	-3.27	-3.16	-3.05	-2.95	-2.86	-2.77	-2.68	-2.60	-2.52	-2.45	-2.38	-2.31	-2.25	-2.19	-2.14	.00
0 14	.00	-3.29	-3.17	-3.06	-2.95	-2.86	-2.76	-2.67	-2.59	-2.51	-2.43	-2.36	-2.29	-2.22	-2.16	-2.12	.00
0 15	.00	-3.32	-3.18	-3.06	-2.95	-2.84	-2.75	-2.66	-2.57	-2.49	-2.41	-2.33	-2.26	-2.19	-2.13	-2.06	.00
0 16	.00	-3.32	-3.18	-3.05	-2.93	-2.83	-2.73	-2.63	-2.55	-2.46	-2.38	-2.30	-2.23	-2.16	-2.09	-2.01	.00
0 17	.00	-3.28	-3.15	-3.03	-2.91	-2.80	-2.70	-2.61	-2.52	-2.43	-2.35	-2.27	-2.20	-2.13	-2.05	-1.98	.00
0 18	.00	-3.25	-3.12	-2.99	-2.88	-2.77	-2.67	-2.57	-2.48	-2.40	-2.32	-2.24	-2.16	-2.09	-2.02	-1.96	.00
0 19	.00	-3.20	-3.08	-2.95	-2.84	-2.73	-2.63	-2.53	-2.44	-2.36	-2.28	-2.20	-2.13	-2.06	-1.99	-1.93	.00
0 20	.00	-3.17	-3.03	-2.91	-2.79	-2.68	-2.58	-2.48	-2.39	-2.31	-2.23	-2.16	-2.09	-2.02	-1.95	-1.89	.00
0 21	.00	-3.13	-2.99	-2.86	-2.74	-2.62	-2.52	-2.43	-2.34	-2.26	-2.18	-2.11	-2.04	-1.98	-1.92	-1.86	.00
0 22	.00	-3.07	-2.93	-2.79	-2.67	-2.56	-2.46	-2.36	-2.28	-2.20	-2.13	-2.06	-2.00	-1.94	-1.88	-1.83	.00
0 23	.00	-3.03	-2.87	-2.72	-2.59	-2.48	-2.38	-2.29	-2.21	-2.14	-2.07	-2.01	-1.95	-1.89	-1.83	-1.78	.00
0 24	.00	-2.97	-2.79	-2.63	-2.50	-2.39	-2.29	-2.21	-2.13	-2.06	-2.00	-1.95	-1.89	-1.84	-1.79	-1.75	.00
0 25	.00	-2.87	-2.67	-2.52	-2.39	-2.28	-2.19	-2.11	-2.05	-1.99	-1.93	-1.88	-1.84	-1.79	-1.75	-1.72	.00
0 26	.00	-2.74	-2.53	-2.37	-2.25	-2.16	-2.08	-2.01	-1.95	-1.90	-1.86	-1.81	-1.78	-1.74	-1.71	-1.66	.00
0 27	.00	-2.48	-2.32	-2.19	-2.09	-2.02	-1.96	-1.90	-1.85	-1.81	-1.77	-1.74	-1.72	-1.69	-1.67	-1.64	.00
0 28	.00	-2.16	-2.07	-1.99	-1.91	-1.87	-1.83	-1.79	-1.74	-1.71	-1.69	-1.67	-1.66	-1.65	-1.63	-1.62	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

0DRAWDOWN WILL BE SAVED ON UNIT 40 AT END OF TIME STEP 1, STRESS PERIOD 1

0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 1

0

CUMULATIVE VOLUMES	L**3		RATES FOR THIS TIME STEP	L**3/T	
IN:			IN:		
STORAGE =	.00000		STORAGE =	.00000	
CONSTANT HEAD =	.11245E+07		CONSTANT HEAD =	616.15	
RECHARGE =	.56461E+07		RECHARGE =	3093.7	
0 TOTAL IN =	.67706E+07		TOTAL IN =	3709.9	
0 OUT:			OUT:		
STORAGE =	.00000		STORAGE =	.00000	
CONSTANT HEAD =	.67702E+07		CONSTANT HEAD =	3709.7	
RECHARGE =	.00000		RECHARGE =	.00000	
0 TOTAL OUT =	.67702E+07		TOTAL OUT =	3709.7	
0 IN - OUT =	403.50		IN - OUT =	.22119	
0 PERCENT DISCREPANCY =		.01	PERCENT DISCREPANCY =		.01

0

TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
STRESS PERIOD TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
TOTAL SIMULATION TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658

1

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1                    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
0NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY              SIM 1 - CAP
    2 LAYERS         29 ROWS         17 COLUMNS
   1 STRESS PERIOD(S) IN SIMULATION
 MODEL TIME UNIT IS DAYS
0I/O UNITS:
 ELEMENT OF IUNIT:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
         I/O UNIT: 11  0  0  0  0  0  0  0 19  0  0 22  0  0  0  0  0  0  0  0  0  0  0  0
0BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT  1
 ARRAYS RHS AND BUFF WILL SHARE MEMORY.
 START HEAD WILL BE SAVED
     9421 ELEMENTS IN X ARRAY ARE USED BY BAS
     9421 ELEMENTS OF X ARRAY USED OUT OF  100000
0BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 11
 STEADY-STATE SIMULATION
      LAYER  AQUIFER TYPE
      -------------------
         1        1
         2        0
      988 ELEMENTS IN X ARRAY ARE USED BY BCF
    10409 ELEMENTS OF X ARRAY USED OUT OF  100000
0SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 19
 MAXIMUM OF  50 ITERATIONS ALLOWED FOR CLOSURE
  5 ITERATION PARAMETERS
     4149 ELEMENTS IN X ARRAY ARE USED BY SIP
    14558 ELEMENTS OF X ARRAY USED OUT OF  100000
1NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY              SIM 1 - CAP
0
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BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 2	-1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 3	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 4	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 5	-1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 6	-1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 7	-1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 8	-1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 9	-1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 10	-1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
0 11	-1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1
0 12	-1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1
0 13	-1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
0 14	-1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
0 15	-1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1
0 16	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1
0 17	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1
0 18	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 19	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 20	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 21	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 22	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 23	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 24	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 25	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 26	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1
0 27	-1	-1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
0 28	-1	-1	-1	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
0 29	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

0

BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
0 2	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 3	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 4	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 5	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 6	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 7	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 8	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 9	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 10	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 11	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 12	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 13	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 14	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 15	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 16	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 17	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2

0 18	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 19	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 20	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 21	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 22	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 23	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 24	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 25	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 26	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 27	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 28	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 29	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

0AQUIFER HEAD WILL BE SET TO 999.99 AT ALL NO-FLOW NODES (IBOUND=0).

0

INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	10.00	8.500	7.000	5.000	3.500	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 2	9.300	8.170	6.850	5.240	3.370	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 3	8.700	7.800	6.690	5.350	3.750	1.730	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 4	8.200	7.450	6.520	5.390	4.040	2.350	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 5	7.700	7.100	6.340	5.400	4.280	2.930	1.370	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 6	7.200	6.740	6.140	5.370	4.440	3.310	1.930	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 7	6.700	6.390	5.920	5.310	4.540	3.600	2.470	1.140	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 8	6.200	6.020	5.700	5.230	4.600	3.810	2.820	1.590	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 9	5.700	5.660	5.470	5.130	4.630	3.970	3.110	1.930	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 10	5.200	5.310	5.240	5.020	4.650	4.120	3.420	2.490	1.290	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 11	4.800	4.980	5.010	4.900	4.650	4.250	3.700	2.990	2.120	1.140	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 12	4.300	4.630	4.780	4.780	4.640	4.360	3.940	3.400	2.720	1.940	1.030	.0000	.0000	.0000	.0000	.0000	.0000
0 13	3.800	4.290	4.560	4.650	4.610	4.430	4.130	3.710	3.170	2.520	1.760	.8800	.0000	.0000	.0000	.0000	.0000
0 14	3.500	4.000	4.340	4.520	4.560	4.470	4.260	3.940	3.500	2.960	2.270	1.380	.0000	.0000	.0000	.0000	.0000
0 15	3.100	3.700	4.110	4.370	4.490	4.480	4.350	4.110	3.760	3.290	2.700	1.960	1.010	.0000	.0000	.0000	.0000
0 16	2.700	3.380	3.870	4.200	4.390	4.450	4.390	4.220	3.940	3.550	3.050	2.420	1.660	.8200	.0000	.0000	.0000
0 17	2.200	3.020	3.610	4.020	4.270	4.390	4.390	4.280	4.060	3.730	3.300	2.750	2.080	1.230	.0000	.0000	.0000
0 18	1.700	2.650	3.330	3.810	4.130	4.300	4.350	4.290	4.120	3.850	3.470	2.990	2.390	1.660	.7900	.0000	.0000
0 19	1.200	2.280	3.050	3.590	3.960	4.180	4.270	4.250	4.120	3.890	3.560	3.130	2.600	1.940	1.120	.0000	.0000
0 20	.7000	1.910	2.760	3.350	3.760	4.020	4.140	4.150	4.060	3.870	3.580	3.190	2.700	2.110	1.410	.6200	.0000
0 21	.2000	1.570	2.480	3.110	3.540	3.820	3.970	4.010	3.940	3.770	3.510	3.160	2.700	2.150	1.490	.7600	.0000
0 22	.0000	1.310	2.210	2.850	3.300	3.590	3.760	3.810	3.760	3.610	3.360	3.030	2.590	2.050	1.390	.6200	.0000
0 23	.0000	1.090	1.930	2.560	3.010	3.310	3.490	3.540	3.500	3.360	3.130	2.810	2.390	1.840	1.120	.0000	.0000
0 24	.0000	.7600	1.590	2.230	2.680	2.980	3.150	3.210	3.160	3.020	2.800	2.490	2.080	1.560	.9000	.0000	.0000
0 25	.0000	.0000	1.150	1.840	2.290	2.580	2.750	2.790	2.730	2.580	2.350	2.040	1.640	1.180	.6000	.0000	.0000
0 26	.0000	.0000	.8400	1.420	1.840	2.110	2.250	2.280	2.190	2.000	1.770	1.450	1.010	.6300	.0000	.0000	.0000
0 27	.0000	.0000	.5000	.8800	1.280	1.540	1.650	1.650	1.500	1.220	1.000	.7000	.0000	.0000	.0000	.0000	.0000
0 28	.0000	.0000	.0000	.0000	.6100	.8500	.9300	.8900	.6800	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 29	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

0

INITIAL HEAD FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.2)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

```
0  1     2.900      2.900      2.800      2.800      2.800      2.700      2.700      2.700      2.600      2.600
         2.600      2.500      2.500      2.500      2.400      2.400      2.400
0  2     2.900      2.880      2.840      2.820      2.790      2.740      2.700      2.670      2.620      2.590
         2.560      2.510      2.490      2.460      2.410      2.390      2.400
0  3     2.900      2.890      2.860      2.830      2.790      2.750      2.710      2.670      2.630      2.590
         2.550      2.510      2.470      2.430      2.390      2.360      2.300
0  4     2.900      2.910      2.890      2.850      2.810      2.760      2.720      2.670      2.630      2.580
         2.540      2.500      2.460      2.420      2.380      2.340      2.300
0  5     3.000      2.960      2.920      2.880      2.830      2.780      2.730      2.680      2.630      2.580
         2.530      2.490      2.440      2.400      2.360      2.330      2.300
0  6     3.100      3.020      2.960      2.900      2.850      2.790      2.740      2.680      2.630      2.580
         2.530      2.480      2.430      2.390      2.350      2.310      2.300
0  7     3.100      3.040      2.980      2.930      2.870      2.810      2.740      2.690      2.630      2.570
         2.520      2.470      2.420      2.370      2.320      2.270      2.200
0  8     3.100      3.070      3.010      2.950      2.880      2.820      2.750      2.690      2.630      2.570
         2.510      2.450      2.400      2.350      2.300      2.250      2.200
0  9     3.200      3.110      3.040      2.970      2.900      2.830      2.760      2.690      2.630      2.560
         2.500      2.440      2.390      2.330      2.280      2.240      2.200
0 10     3.200      3.150      3.070      3.000      2.920      2.840      2.770      2.690      2.620      2.560
         2.490      2.430      2.370      2.320      2.260      2.220      2.200
0 11     3.300      3.190      3.100      3.020      2.930      2.850      2.770      2.690      2.620      2.550
         2.480      2.410      2.350      2.290      2.240      2.180      2.100
0 12     3.300      3.220      3.130      3.040      2.940      2.860      2.770      2.690      2.610      2.540
         2.470      2.400      2.330      2.270      2.210      2.160      2.100
0 13     3.400      3.270      3.160      3.050      2.950      2.860      2.770      2.680      2.600      2.520
         2.450      2.380      2.310      2.250      2.190      2.140      2.100
0 14     3.400      3.290      3.170      3.060      2.950      2.860      2.760      2.670      2.590      2.510
         2.430      2.360      2.290      2.220      2.160      2.120      2.100
0 15     3.500      3.320      3.180      3.060      2.950      2.840      2.750      2.660      2.570      2.490
         2.410      2.330      2.260      2.190      2.130      2.060      2.000
0 16     3.500      3.320      3.180      3.050      2.930      2.830      2.730      2.630      2.550      2.460
         2.380      2.300      2.230      2.160      2.090      2.010      1.900
0 17     3.400      3.280      3.150      3.030      2.910      2.800      2.700      2.610      2.520      2.430
         2.350      2.270      2.200      2.130      2.050      1.980      1.900
0 18     3.400      3.250      3.120      2.990      2.880      2.770      2.670      2.570      2.480      2.400
         2.320      2.240      2.160      2.090      2.020      1.960      1.900
0 19     3.300      3.200      3.080      2.950      2.840      2.730      2.630      2.530      2.440      2.360
         2.280      2.200      2.130      2.060      1.990      1.930      1.900
0 20     3.300      3.170      3.030      2.910      2.790      2.680      2.580      2.480      2.390      2.310
         2.230      2.160      2.090      2.020      1.950      1.890      1.800
0 21     3.300      3.130      2.990      2.860      2.740      2.620      2.520      2.430      2.340      2.260
         2.180      2.110      2.040      1.980      1.920      1.860      1.800
0 22     3.200      3.070      2.930      2.790      2.670      2.560      2.460      2.360      2.280      2.200
         2.130      2.060      2.000      1.940      1.880      1.830      1.800
0 23     3.200      3.030      2.870      2.720      2.590      2.480      2.380      2.290      2.210      2.140
         2.070      2.010      1.950      1.890      1.830      1.780      1.700
0 24     3.200      2.970      2.790      2.630      2.500      2.390      2.290      2.210      2.130      2.060
         2.000      1.950      1.890      1.840      1.790      1.750      1.700
0 25     3.100      2.870      2.670      2.520      2.390      2.280      2.190      2.110      2.050      1.990
         1.930      1.880      1.840      1.790      1.750      1.720      1.700
0 26     3.100      2.740      2.530      2.370      2.250      2.160      2.080      2.010      1.950      1.900
         1.860      1.810      1.780      1.740      1.710      1.660      1.600
0 27     2.700      2.480      2.320      2.290      2.090      2.020      1.960      1.900      1.850      1.810
         1.770      1.740      1.720      1.690      1.670      1.640      1.600
0 28     2.300      2.160      2.070      1.990      1.910      1.870      1.830      1.790      1.740      1.710
         1.690      1.670      1.660      1.650      1.630      1.620      1.600
0 29     1.800      1.800      1.800      1.800      1.700      1.700      1.700      1.700      1.600      1.600
         1.600      1.600      1.600      1.600      1.600      1.600      1.600
0HEAD PRINT FORMAT IS FORMAT NUMBER   4    DRAWDOWN PRINT FORMAT IS FORMAT NUMBER   9
0HEADS WILL BE SAVED ON UNIT 30    DRAWDOWNS WILL BE SAVED ON UNIT 40
0OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
0                                                   COLUMN TO ROW ANISOTROPY =    1.000000
0                                                                      DELR =    50.00000
0                                                                      DELC =    50.00000
0                                                      HYD. COND. ALONG ROWS =    6.500000     FOR LAYER  1
0                                                                    BOTTOM =   -6.900000     FOR LAYER  1
0                                                   VERT HYD COND /THICKNESS =    .1000000E-04 FOR LAYER  1
0                                                       TRANSMIS. ALONG ROWS =    41.00000     FOR LAYER  2
0


                                                        SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE
                                                        -------------------------------------------
0                                            MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =        50
                                                           ACCELERATION PARAMETER =      1.0000
                                                 HEAD CHANGE CRITERION FOR CLOSURE =      .10000E-02
                                                 SIP HEAD CHANGE PRINTOUT INTERVAL =        1
0                                                CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED
1                                               STRESS PERIOD NO.   1, LENGTH =   1825.000
                                                --------------------------------------------

                                                NUMBER OF TIME STEPS =       1

                                                 MULTIPLIER FOR DELT =      1.000

                                              INITIAL TIME STEP SIZE =    1825.000
0AVERAGE SEED =  .00031901
 MINIMUM SEED =  .00015380
0
```

5 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

.0000000E+00 .8663557E+00 .9821392E+00 .9976130E+00 .9996810E+00

0

14 ITERATIONS FOR TIME STEP 1 IN STRESS PERIOD 1

0MAXIMUM HEAD CHANGE FOR EACH ITERATION:

HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL
-.3038	(1, 25, 5)	-.8700	(1, 22, 9)	-1.925	(1, 18, 9)	-.6047	(1, 22, 7)	.2037	(1, 14, 10)
-.3767E-01	(1, 11, 8)	-.6338E-01	(1, 13, 9)	-.1756E-01	(1, 13, 5)	-.1720E-01	(1, 17, 9)	.4688E-02	(1, 15, 7)
.1312E-02	(1, 19, 10)	.1190E-02	(1, 19, 10)	.1757E-02	(1, 17, 9)	.3584E-03	(1, 21, 5)		

0

0HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 1 CELL-BY-CELL FLOW TERM FLAG = 0

0OUTPUT FLAGS FOR EACH LAYER:

LAYER	HEAD PRINTOUT	DRAWDOWN PRINTOUT	HEAD SAVE	DRAWDOWN SAVE
1	1	1	1	1
2	1	1	1	1

1 HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	10.00	8.50	7.00	5.00	3.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	9.30	8.04	6.63	4.98	3.12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 3	8.70	7.59	6.32	4.89	3.28	1.39	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 4	8.20	7.17	6.04	4.78	3.40	1.84	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 5	7.70	6.77	5.75	4.65	3.47	2.20	.92	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 6	7.20	6.36	5.46	4.50	3.47	2.39	1.26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 7	6.70	5.96	5.16	4.31	3.42	2.49	1.54	.62	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 8	6.20	5.55	4.85	4.10	3.32	2.51	1.68	.84	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 9	5.70	5.14	4.53	3.88	3.19	2.48	1.74	.95	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 10	5.20	4.73	4.20	3.63	3.04	2.42	1.79	1.14	.49	.00	.00	.00	.00	.00	.00	.00	.00
0 11	4.80	4.35	3.88	3.38	2.87	2.34	1.80	1.26	.75	.33	.00	.00	.00	.00	.00	.00	.00
0 12	4.30	3.94	3.55	3.13	2.68	2.23	1.77	1.32	.90	.53	.23	.00	.00	.00	.00	.00	.00
0 13	3.80	3.55	3.22	2.86	2.48	2.10	1.71	1.33	.97	.65	.38	.15	.00	.00	.00	.00	.00
0 14	3.50	3.21	2.91	2.60	2.28	1.95	1.61	1.29	.99	.71	.46	.23	.00	.00	.00	.00	.00
0 15	3.10	2.85	2.59	2.33	2.06	1.78	1.50	1.23	.97	.73	.51	.31	.13	.00	.00	.00	.00
0 16	2.70	2.48	2.26	2.05	1.83	1.60	1.37	1.14	.92	.72	.52	.35	.20	.08	.00	.00	.00
0 17	2.20	2.07	1.92	1.76	1.59	1.41	1.23	1.04	.86	.68	.52	.37	.23	.12	.00	.00	.00
0 18	1.70	1.65	1.57	1.47	1.36	1.22	1.08	.93	.78	.64	.50	.37	.25	.15	.06	.00	.00
0 19	1.20	1.24	1.23	1.19	1.13	1.04	.93	.82	.70	.58	.46	.35	.25	.16	.08	.00	.00
0 20	.70	.84	.91	.93	.91	.86	.79	.70	.61	.51	.42	.33	.24	.16	.09	.03	.00
0 21	.20	.49	.64	.70	.71	.69	.65	.59	.52	.45	.37	.29	.22	.15	.09	.04	.00
0 22	.00	.28	.43	.51	.55	.55	.53	.49	.43	.38	.31	.25	.19	.13	.08	.03	.00
0 23	.00	.16	.29	.37	.41	.43	.42	.39	.35	.31	.26	.21	.16	.11	.06	.00	.00
0 24	.00	.09	.19	.26	.30	.32	.32	.30	.28	.24	.21	.17	.12	.08	.04	.00	.00
0 25	.00	.00	.11	.17	.21	.23	.24	.23	.21	.18	.15	.12	.09	.06	.02	.00	.00
0 26	.00	.00	.06	.11	.14	.16	.17	.16	.15	.12	.10	.08	.05	.03	.00	.00	.00
0 27	.00	.00	.03	.06	.08	.10	.10	.10	.09	.07	.05	.03	.00	.00	.00	.00	.00
0 28	.00	.00	.00	.00	.03	.04	.05	.05	.03	.00	.00	.00	.00	.00	.00	.00	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

1 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

0 1	2.90	2.90	2.80	2.80	2.80	2.70	2.70	2.70	2.60	2.60	2.60	2.50	2.50	2.50	2.40
	2.40	2.40													
0 2	2.90	2.88	2.84	2.81	2.78	2.73	2.70	2.67	2.62	2.59	2.56	2.51	2.48	2.46	2.41
	2.39	2.40													
0 3	2.90	2.89	2.86	2.83	2.79	2.75	2.71	2.67	2.62	2.58	2.55	2.51	2.47	2.43	2.39
	2.36	2.30													
0 4	2.90	2.91	2.88	2.85	2.80	2.76	2.71	2.67	2.62	2.58	2.54	2.49	2.45	2.42	2.38
	2.34	2.30													
0 5	3.00	2.96	2.92	2.87	2.82	2.77	2.72	2.67	2.62	2.57	2.53	2.48	2.44	2.40	2.36
	2.33	2.30													
0 6	3.10	3.01	2.95	2.89	2.84	2.78	2.73	2.67	2.62	2.57	2.52	2.47	2.43	2.38	2.34
	2.31	2.30													
0 7	3.10	3.04	2.98	2.92	2.86	2.79	2.73	2.67	2.62	2.56	2.51	2.46	2.41	2.36	2.32
	2.27	2.20													
0 8	3.10	3.06	3.00	2.94	2.87	2.81	2.74	2.68	2.61	2.56	2.50	2.45	2.39	2.35	2.30
	2.25	2.20													
0 9	3.20	3.11	3.03	2.96	2.89	2.82	2.74	2.68	2.61	2.55	2.49	2.43	2.38	2.33	2.28
	2.24	2.20													
0 10	3.20	3.14	3.06	2.98	2.90	2.82	2.75	2.68	2.61	2.54	2.48	2.42	2.36	2.31	2.26
	2.22	2.20													
0 11	3.30	3.19	3.09	3.00	2.92	2.83	2.75	2.67	2.60	2.53	2.46	2.40	2.34	2.29	2.23
	2.18	2.10													
0 12	3.30	3.22	3.12	3.02	2.92	2.83	2.75	2.67	2.59	2.52	2.45	2.38	2.32	2.26	2.21
	2.15	2.10													
0 13	3.40	3.26	3.14	3.03	2.93	2.83	2.74	2.66	2.58	2.50	2.43	2.36	2.30	2.24	2.18
	2.14	2.10													
0 14	3.40	3.28	3.16	3.04	2.93	2.83	2.73	2.64	2.56	2.48	2.41	2.34	2.27	2.21	2.15
	2.11	2.10													
0 15	3.50	3.32	3.17	3.04	2.92	2.82	2.72	2.62	2.54	2.46	2.38	2.31	2.24	2.18	2.12
	2.06	2.00													
0 16	3.50	3.31	3.16	3.03	2.91	2.80	2.70	2.60	2.51	2.43	2.35	2.28	2.21	2.14	2.07
	2.00	1.90													
0 17	3.40	3.27	3.13	3.00	2.88	2.77	2.67	2.57	2.48	2.40	2.32	2.24	2.17	2.11	2.04
	1.97	1.90													
0 18	3.40	3.24	3.10	2.97	2.85	2.74	2.63	2.54	2.44	2.36	2.28	2.21	2.14	2.07	2.01
	1.95	1.90													
0 19	3.30	3.19	3.06	2.93	2.81	2.70	2.59	2.49	2.40	2.32	2.24	2.17	2.10	2.04	1.98
	1.93	1.90													
0 20	3.30	3.16	3.02	2.89	2.76	2.65	2.54	2.45	2.36	2.27	2.20	2.13	2.06	2.00	1.94
	1.88	1.80													
0 21	3.30	3.12	2.97	2.84	2.71	2.59	2.49	2.39	2.30	2.22	2.15	2.08	2.02	1.96	1.90
	1.85	1.80													
0 22	3.20	3.06	2.92	2.77	2.65	2.53	2.42	2.33	2.24	2.17	2.10	2.03	1.97	1.92	1.87
	1.82	1.80													
0 23	3.20	3.02	2.85	2.70	2.57	2.45	2.35	2.26	2.18	2.11	2.04	1.98	1.93	1.87	1.82
	1.77	1.70													
0 24	3.20	2.97	2.77	2.61	2.48	2.37	2.27	2.18	2.10	2.04	1.98	1.92	1.87	1.83	1.78
	1.74	1.70													
0 25	3.10	2.87	2.67	2.50	2.37	2.26	2.17	2.09	2.02	1.96	1.91	1.86	1.82	1.78	1.74
	1.71	1.70													
0 26	3.10	2.74	2.52	2.36	2.24	2.14	2.06	2.00	1.93	1.88	1.84	1.80	1.77	1.73	1.70
	1.66	1.60													
0 27	2.70	2.48	2.31	2.19	2.09	2.01	1.95	1.89	1.84	1.80	1.76	1.74	1.71	1.69	1.66
	1.63	1.60													
0 28	2.30	2.16	2.07	1.99	1.91	1.86	1.82	1.79	1.73	1.70	1.68	1.67	1.66	1.64	1.63
	1.62	1.60													
0 29	1.80	1.80	1.80	1.80	1.70	1.70	1.70	1.70	1.60	1.60	1.60	1.60	1.60	1.60	1.60
	1.60	1.60													

0HEAD WILL BE SAVED ON UNIT 30 AT END OF TIME STEP 1, STRESS PERIOD 1

1 DRAWDOWN IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	.00	.13	.22	.26	.25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 3	.00	.21	.37	.46	.47	.34	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 4	.00	.28	.48	.61	.64	.51	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 5	.00	.33	.59	.75	.81	.73	.45	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 6	.00	.38	.68	.87	.97	.92	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 7	.00	.43	.76	1.00	1.12	1.11	.93	.52	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 8	.00	.47	.85	1.13	1.28	1.30	1.14	.75	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 9	.00	.52	.94	1.25	1.44	1.49	1.37	.98	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 10	.00	.58	1.04	1.39	1.61	1.70	1.63	1.35	.80	.00	.00	.00	.00	.00	.00	.00	.00
0 11	.00	.63	1.13	1.52	1.78	1.91	1.90	1.73	1.37	.81	.00	.00	.00	.00	.00	.00	.00
0 12	.00	.69	1.23	1.65	1.96	2.13	2.17	2.08	1.82	1.41	.80	.00	.00	.00	.00	.00	.00
0 13	.00	.74	1.34	1.79	2.13	2.33	2.42	2.38	2.20	1.87	1.38	.73	.00	.00	.00	.00	.00
0 14	.00	.79	1.43	1.92	2.28	2.52	2.65	2.65	2.51	2.25	1.81	1.15	.00	.00	.00	.00	.00
0 15	.00	.85	1.52	2.04	2.43	2.70	2.85	2.88	2.79	2.56	2.19	1.65	.88	.00	.00	.00	.00
0 16	.00	.90	1.61	2.15	2.56	2.85	3.02	3.08	3.02	2.83	2.53	2.07	1.46	.74	.00	.00	.00
0 17	.00	.95	1.69	2.26	2.68	2.98	3.16	3.24	3.20	3.05	2.78	2.38	1.85	1.11	.00	.00	.00
0 18	.00	1.00	1.76	2.34	2.77	3.08	3.27	3.36	3.34	3.21	2.97	2.62	2.14	1.51	.73	.00	.00
0 19	.00	1.04	1.82	2.40	2.83	3.14	3.34	3.43	3.42	3.31	3.10	2.78	2.35	1.78	1.04	.00	.00
0 20	.00	1.07	1.85	2.42	2.85	3.16	3.35	3.45	3.45	3.36	3.16	2.86	2.46	1.95	1.32	.59	.00
0 21	.00	1.08	1.84	2.41	2.83	3.13	3.32	3.42	3.42	3.32	3.14	2.87	2.48	2.00	1.40	.72	.00
0 22	.00	1.03	1.78	2.34	2.75	3.04	3.23	3.32	3.33	3.23	3.05	2.78	2.40	1.92	1.31	.59	.00
0 23	.00	.93	1.64	2.19	2.60	2.88	3.07	3.15	3.15	3.05	2.87	2.60	2.23	1.73	1.06	.00	.00
0 24	.00	.67	1.40	1.97	2.38	2.66	2.83	2.91	2.88	2.78	2.59	2.32	1.96	1.48	.86	.00	.00
0 25	.00	.00	1.04	1.67	2.08	2.35	2.51	2.56	2.52	2.40	2.20	1.92	1.55	1.12	.58	.00	.00

0 26	.00	.00	.78	1.31	1.70	1.95	2.08	2.12	2.04	1.88	1.67	1.37	.96	.60	.00	.00	.00
0 27	.00	.00	.47	.82	1.20	1.44	1.55	1.55	1.41	1.15	.95	.67	.00	.00	.00	.00	.00
0 28	.00	.00	.00	.00	.58	.81	.88	.84	.65	.00	.00	.00	.00	.00	.00	.00	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

1 DRAWDOWN IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	.00	-.00	.00	.01	.01	.01	-.00	-.00	-.00	-.00	-.00	-.00	.01	.00	.00	-.00	.00
0 3	.00	.00	.00	.00	-.00	.00	.00	.00	.01	.01	.00	.00	.00	-.00	-.00	.00	.00
0 4	.00	.00	.01	.00	.01	.00	.01	.00	.01	.00	.00	.01	.01	.00	.00	.00	.00
0 5	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.00	.01	.00	.00	-.00	.00	.00
0 6	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.00	.01	.01	.00	.00
0 7	.00	.00	.00	.01	.01	.02	.01	.02	.01	.01	.01	.01	.01	.01	.00	.00	.00
0 8	.00	.01	.01	.01	.01	.01	.01	.01	.02	.01	.01	.00	.01	.00	.00	.00	.00
0 9	.00	.00	.01	.01	.01	.01	.02	.01	.02	.01	.01	.01	.01	.00	.00	.00	.00
0 10	.00	.01	.01	.02	.02	.02	.02	.01	.01	.02	.01	.01	.01	.01	.00	.00	.00
0 11	.00	.00	.01	.02	.01	.02	.02	.02	.02	.02	.02	.01	.01	.00	.01	.00	.00
0 12	.00	.00	.01	.02	.02	.03	.02	.02	.02	.02	.02	.02	.01	.01	.00	.01	.00
0 13	.00	.01	.02	.02	.02	.03	.03	.02	.02	.02	.02	.02	.01	.01	.01	.00	.00
0 14	.00	.01	.01	.02	.02	.03	.03	.03	.03	.03	.02	.02	.02	.01	.01	.01	.00
0 15	.00	.00	.01	.02	.03	.02	.03	.04	.03	.03	.03	.02	.02	.01	.01	.00	.00
0 16	.00	.01	.02	.02	.02	.03	.03	.03	.04	.03	.03	.02	.02	.02	.02	.01	.00
0 17	.00	.01	.02	.03	.03	.03	.03	.04	.04	.03	.03	.03	.03	.02	.01	.01	.00
0 18	.00	.01	.02	.02	.03	.03	.04	.03	.04	.04	.04	.03	.02	.02	.01	.01	.00
0 19	.00	.01	.02	.02	.03	.03	.04	.04	.04	.04	.04	.03	.03	.02	.01	.00	.00
0 20	.00	.01	.01	.02	.03	.03	.04	.03	.03	.04	.03	.03	.03	.02	.01	.01	.00
0 21	.00	.01	.02	.02	.03	.03	.03	.04	.04	.04	.03	.03	.02	.02	.02	.01	.00
0 22	.00	.01	.01	.02	.02	.03	.04	.03	.04	.03	.03	.03	.03	.02	.01	.01	.00
0 23	.00	.01	.02	.02	.02	.03	.03	.03	.03	.03	.03	.03	.02	.02	.01	.01	.00
0 24	.00	.00	.02	.02	.02	.02	.02	.03	.03	.02	.02	.03	.02	.01	.01	.01	.00
0 25	.00	.00	.00	.02	.02	.02	.02	.02	.03	.03	.02	.02	.02	.01	.01	.01	.00
0 26	.00	.00	.01	.01	.01	.02	.02	.01	.02	.02	.02	.01	.01	.01	.01	-.00	.00
0 27	.00	.00	.01	.10	.00	.01	.01	.01	.01	.01	.01	.00	.01	.00	.01	.01	.00
0 28	.00	.00	.00	.00	.00	.01	.01	.00	.01	.01	.01	.00	.00	.01	.00	.00	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

0DRAWDOWN WILL BE SAVED ON UNIT 40 AT END OF TIME STEP 1, STRESS PERIOD 1

0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 1

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.00000	STORAGE =	.00000
CONSTANT HEAD =	.19779E+07	CONSTANT HEAD =	1083.8
TOTAL IN =	.19779E+07	TOTAL IN =	1083.8
OUT:		OUT:	
STORAGE =	.00000	STORAGE =	.00000
CONSTANT HEAD =	.19779E+07	CONSTANT HEAD =	1083.8
TOTAL OUT =	.19779E+07	TOTAL OUT =	1083.8
IN - OUT =	-5.3750	IN - OUT =	-.29297E-02
PERCENT DISCREPANCY =	.00	PERCENT DISCREPANCY =	.00

0

TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
STRESS PERIOD TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
TOTAL SIMULATION TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658

1

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1                    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
0NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY              SIM 2 - CAP, SHALLOW/DEEP EXTRACT
    2 LAYERS         29 ROWS         17 COLUMNS
   1 STRESS PERIOD(S) IN SIMULATION
 MODEL TIME UNIT IS DAYS
0I/O UNITS:
 ELEMENT OF IUNIT:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
         I/O UNIT: 11 12  0  0  0  0  0  0 19  0  0 22  0  0  0  0  0  0  0  0  0  0  0  0
0BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT  1
 ARRAYS RHS AND BUFF WILL SHARE MEMORY.
 START HEAD WILL BE SAVED
     9421 ELEMENTS IN X ARRAY ARE USED BY BAS
     9421 ELEMENTS OF X ARRAY USED OUT OF  100000
0BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 11
 STEADY-STATE SIMULATION
      LAYER  AQUIFER TYPE
      -------------------
         1          1
         2          0
      988 ELEMENTS IN X ARRAY ARE USED BY BCF
    10409 ELEMENTS OF X ARRAY USED OUT OF  100000
0WEL1 -- WELL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM 12
 MAXIMUM OF   23 WELLS
       92 ELEMENTS IN X ARRAY ARE USED FOR WELLS
    10501 ELEMENTS OF X ARRAY USED OUT OF  100000
0SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 19
 MAXIMUM OF  50 ITERATIONS ALLOWED FOR CLOSURE
  5 ITERATION PARAMETERS
     4149 ELEMENTS IN X ARRAY ARE USED BY SIP
    14650 ELEMENTS OF X ARRAY USED OUT OF  100000
1NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY              SIM 2 - CAP, SHALLOW/DEEP EXTRACT
0
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BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 2	-1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 3	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 4	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 5	-1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 6	-1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 7	-1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 8	-1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 9	-1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 10	-1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
0 11	-1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1
0 12	-1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1
0 13	-1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
0 14	-1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
0 15	-1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1
0 16	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1
0 17	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1
0 18	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 19	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 20	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 21	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 22	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 23	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 24	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 25	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 26	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1
0 27	-1	-1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
0 28	-1	-1	-1	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
0 29	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

0

BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
0 2	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 3	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 4	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 5	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 6	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 7	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 8	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 9	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 10	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 11	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 12	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 13	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2

```
0 14   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 15   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 16   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 17   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 18   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 19   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 20   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 21   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 22   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 23   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 24   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 25   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 26   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 27   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 28   -2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2  -2
0 29   -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2
0AQUIFER HEAD WILL BE SET TO  999.99     AT ALL NO-FLOW NODES (IBOUND=0).
0
```

INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	10.00	8.500	7.000	5.000	3.500	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 2	9.300	8.170	6.850	5.240	3.370	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 3	8.700	7.800	6.690	5.350	3.750	1.730	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 4	8.200	7.450	6.520	5.390	4.040	2.350	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 5	7.700	7.100	6.340	5.400	4.280	2.930	1.370	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 6	7.200	6.740	6.140	5.370	4.440	3.310	1.930	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 7	6.700	6.390	5.920	5.310	4.540	3.600	2.470	1.140	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 8	6.200	6.020	5.700	5.230	4.600	3.810	2.820	1.590	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 9	5.700	5.660	5.470	5.130	4.630	3.970	3.110	1.930	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 10	5.200	5.310	5.240	5.020	4.650	4.120	3.420	2.490	1.290	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 11	4.800	4.980	5.010	4.900	4.650	4.250	3.700	2.990	2.120	1.140	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 12	4.300	4.630	4.780	4.780	4.640	4.360	3.940	3.400	2.720	1.940	1.030	.0000	.0000	.0000	.0000	.0000	.0000
0 13	3.800	4.290	4.560	4.650	4.610	4.430	4.130	3.710	3.170	2.520	1.760	.8800	.0000	.0000	.0000	.0000	.0000
0 14	3.500	4.000	4.340	4.520	4.560	4.470	4.260	3.940	3.500	2.960	2.270	1.380	.0000	.0000	.0000	.0000	.0000
0 15	3.100	3.700	4.110	4.370	4.490	4.480	4.350	4.110	3.760	3.290	2.700	1.960	1.010	.0000	.0000	.0000	.0000
0 16	2.700	3.380	3.870	4.200	4.390	4.450	4.390	4.220	3.940	3.550	3.050	2.420	1.660	.8200	.0000	.0000	.0000
0 17	2.200	3.020	3.610	4.020	4.270	4.390	4.390	4.280	4.060	3.730	3.300	2.750	2.080	1.230	.0000	.0000	.0000
0 18	1.700	2.650	3.330	3.810	4.130	4.300	4.350	4.290	4.120	3.850	3.470	2.990	2.390	1.660	.7900	.0000	.0000
0 19	1.200	2.280	3.050	3.590	3.960	4.180	4.270	4.250	4.120	3.890	3.560	3.130	2.600	1.940	1.120	.0000	.0000
0 20	.7000	1.910	2.760	3.350	3.760	4.020	4.140	4.150	4.060	3.870	3.580	3.190	2.700	2.110	1.410	.6200	.0000
0 21	.2000	1.570	2.480	3.110	3.540	3.820	3.970	4.010	3.940	3.770	3.510	3.160	2.700	2.150	1.490	.7600	.0000
0 22	.0000	1.310	2.210	2.850	3.300	3.590	3.760	3.810	3.760	3.610	3.360	3.030	2.590	2.050	1.390	.6200	.0000
0 23	.0000	1.090	1.930	2.560	3.010	3.310	3.490	3.540	3.500	3.360	3.130	2.810	2.390	1.840	1.120	.0000	.0000
0 24	.0000	.7600	1.590	2.230	2.680	2.980	3.150	3.210	3.160	3.020	2.800	2.490	2.080	1.560	.9000	.0000	.0000
0 25	.0000	.0000	1.150	1.840	2.290	2.580	2.750	2.790	2.730	2.580	2.350	2.040	1.640	1.180	.6000	.0000	.0000
0 26	.0000	.0000	.8400	1.420	1.840	2.110	2.250	2.280	2.190	2.000	1.770	1.450	1.010	.6300	.0000	.0000	.0000
0 27	.0000	.0000	.5000	.8800	1.280	1.540	1.650	1.650	1.500	1.220	1.000	.7000	.0000	.0000	.0000	.0000	.0000
0 28	.0000	.0000	.0000	.0000	.6100	.8500	.9300	.8900	.6800	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 29	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

0

INITIAL HEAD FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	2.900	2.900	2.800	2.800	2.800	2.700	2.700	2.700	2.600	2.600	2.600	2.500	2.500	2.500	2.400	2.400	2.400
0 2	2.900	2.880	2.840	2.820	2.790	2.740	2.700	2.670	2.620	2.590	2.560	2.510	2.490	2.460	2.410	2.390	2.400
0 3	2.900	2.890	2.860	2.830	2.790	2.750	2.710	2.670	2.630	2.590	2.550	2.510	2.470	2.430	2.390	2.360	2.300
0 4	2.900	2.910	2.890	2.850	2.810	2.760	2.720	2.670	2.630	2.580	2.540	2.500	2.460	2.420	2.380	2.340	2.300
0 5	3.000	2.960	2.920	2.880	2.830	2.780	2.730	2.680	2.630	2.580	2.530	2.490	2.440	2.400	2.360	2.330	2.300
0 6	3.100	3.020	2.960	2.900	2.850	2.790	2.740	2.680	2.630	2.580	2.530	2.480	2.430	2.390	2.350	2.310	2.300
0 7	3.100	3.040	2.980	2.930	2.870	2.810	2.740	2.690	2.630	2.570	2.520	2.470	2.420	2.370	2.320	2.270	2.200
0 8	3.100	3.070	3.010	2.950	2.880	2.820	2.750	2.690	2.630	2.570	2.510	2.450	2.400	2.350	2.300	2.250	2.200
0 9	3.200	3.110	3.040	2.970	2.900	2.830	2.760	2.690	2.630	2.560	2.500	2.440	2.390	2.330	2.280	2.240	2.200
0 10	3.200	3.150	3.070	3.000	2.920	2.840	2.770	2.690	2.620	2.560	2.490	2.430	2.370	2.320	2.260	2.220	2.200
0 11	3.300	3.190	3.100	3.020	2.930	2.850	2.770	2.690	2.620	2.550	2.480	2.410	2.350	2.290	2.240	2.180	2.100
0 12	3.300	3.220	3.130	3.040	2.940	2.860	2.770	2.690	2.610	2.540	2.470	2.400	2.330	2.270	2.210	2.160	2.100
0 13	3.400	3.270	3.160	3.050	2.950	2.860	2.770	2.680	2.600	2.520	2.450	2.380	2.310	2.250	2.190	2.140	2.100
0 14	3.400	3.290	3.170	3.060	2.950	2.860	2.760	2.670	2.590	2.510	2.430	2.360	2.290	2.220	2.160	2.120	2.100
0 15	3.500	3.320	3.180	3.060	2.950	2.840	2.750	2.660	2.570	2.490	2.410	2.330	2.260	2.190	2.130	2.060	2.000
0 16	3.500	3.320	3.180	3.050	2.930	2.830	2.730	2.630	2.550	2.460	2.380	2.300	2.230	2.160	2.090	2.010	1.900
0 17	3.400	3.280	3.150	3.030	2.910	2.800	2.700	2.610	2.520	2.430	2.350	2.270	2.200	2.130	2.050	1.980	1.900
0 18	3.400	3.250	3.120	2.990	2.880	2.770	2.670	2.570	2.480	2.400	2.320	2.240	2.160	2.090	2.020	1.960	1.900
0 19	3.300	3.200	3.080	2.950	2.840	2.730	2.630	2.530	2.440	2.360	2.280	2.200	2.130	2.060	1.990	1.930	1.900
0 20	3.300	3.170	3.030	2.910	2.790	2.680	2.580	2.480	2.390	2.310	2.230	2.160	2.090	2.020	1.950	1.890	1.800
0 21	3.300	3.130	2.990	2.860	2.740	2.620	2.520	2.430	2.340	2.260	2.180	2.110	2.040	1.980	1.920	1.860	1.800
0 22	3.200	3.070	2.930	2.790	2.670	2.560	2.460	2.360	2.280	2.200	2.130	2.060	2.000	1.940	1.880	1.830	1.800
0 23	3.200	3.030	2.870	2.720	2.590	2.480	2.380	2.290	2.210	2.140	2.070	2.010	1.950	1.890	1.830	1.780	1.700
0 24	3.200	2.970	2.790	2.630	2.500	2.390	2.290	2.210	2.130	2.060	2.000	1.950	1.890	1.840	1.790	1.750	1.700
0 25	3.100	2.870	2.670	2.520	2.390	2.280	2.190	2.110	2.050	1.990	1.930	1.880	1.840	1.790	1.750	1.720	1.700
0 26	3.100	2.740	2.530	2.370	2.250	2.160	2.080	2.010	1.950	1.900	1.860	1.810	1.780	1.740	1.710	1.660	1.600
0 27	2.700	2.480	2.320	2.290	2.090	2.020	1.960	1.900	1.850	1.810	1.770	1.740	1.720	1.690	1.670	1.640	1.600
0 28	2.300	2.160	2.070	1.990	1.910	1.870	1.830	1.790	1.740	1.710	1.690	1.670	1.660	1.650	1.630	1.620	1.600
0 29	1.800	1.800	1.800	1.800	1.700	1.700	1.700	1.700	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600

```
0HEAD PRINT FORMAT IS FORMAT NUMBER   4    DRAWDOWN PRINT FORMAT IS FORMAT NUMBER   9
0HEADS WILL BE SAVED ON UNIT 30    DRAWDOWNS WILL BE SAVED ON UNIT 40
0OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
0                                    COLUMN TO ROW ANISOTROPY =    1.000000
0                                                        DELR =    50.00000
0                                                        DELC =    50.00000
0                                       HYD. COND. ALONG ROWS =    6.500000     FOR LAYER  1
0                                                      BOTTOM =   -6.900000     FOR LAYER  1
0                                   VERT HYD COND /THICKNESS =    .1000000E-04 FOR LAYER  1
0                                         TRANSMIS. ALONG ROWS =   41.00000     FOR LAYER  2
0

                                         SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE
                                         -------------------------------------------
0                             MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =        50
                                                ACCELERATION PARAMETER =     1.0000
                                    HEAD CHANGE CRITERION FOR CLOSURE =     .10000E-02
                                    SIP HEAD CHANGE PRINTOUT INTERVAL =       1
0                                   CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED
1                                  STRESS PERIOD NO.    1, LENGTH =    1825.000
                                   ----------------------------------------------

                                   NUMBER OF TIME STEPS =      1

                                     MULTIPLIER FOR DELT =     1.000

                                 INITIAL TIME STEP SIZE =   1825.000
```

0 23 WELLS

LAYER	ROW	COL	STRESS RATE	WELL NO.
1	5	5	-529.40	1
1	9	5	-385.00	2
1	13	5	-288.80	3
1	13	9	-144.40	4
1	17	5	-144.40	5
1	17	9	-96.300	6
1	17	13	-144.40	7
1	21	5	-96.300	8
1	21	9	-96.300	9
1	21	13	-96.300	10
1	25	5	-144.40	11
1	25	9	-96.300	12
1	25	13	-192.50	13
2	5	5	-192.50	14
2	9	5	-192.50	15
2	13	5	-192.50	16
2	17	5	-192.50	17
2	17	9	-192.50	18
2	21	5	-192.50	19
2	21	9	-192.50	20
2	21	13	-192.50	21
2	25	5	-192.50	22
2	25	9	-192.50	23

```
0AVERAGE SEED =  .00031901
 MINIMUM SEED =  .00015380
0
    5 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

            .0000000E+00   .8663557E+00   .9821392E+00   .9976130E+00   .9996810E+00
0
    17 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD  1
0MAXIMUM HEAD CHANGE FOR EACH ITERATION:
0 HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL
 -----------------------------------------------------------------------------------------------------------------------------------
   -2.915      (  1,  5,  5)  -1.593      (  1,  9,  5)  -3.812      (  1, 17,  9)  -1.754      (  1, 21,  9)  -.8555      (  1, 21,  9)
   -.2850      (  1, 13,  5)  -.1259      (  1, 13,  9)   .6921E-01 (  2, 13, 11)  -.2989E-01 (  1,  5,  5)  -.1680E-01 (  1,  5,  5)
   -.1414E-01 (  1,  5,  5)  -.6194E-02 (  1,  5,  5)  -.4307E-02 (  1,  5,  5)  -.2492E-02 (  1,  5,  5)  -.1642E-02 (  1,  5,  5)
   -.1301E-02 (  1,  5,  5)  -.5875E-03 (  1,  5,  5)
0
0HEAD/DRAWDOWN PRINTOUT FLAG = 1     TOTAL BUDGET PRINTOUT FLAG = 1     CELL-BY-CELL FLOW TERM FLAG = 0
0OUTPUT FLAGS FOR EACH LAYER:
```

LAYER	HEAD PRINTOUT	DRAWDOWN PRINTOUT	HEAD SAVE	DRAWDOWN SAVE
1	1	1	1	1
2	1	1	1	1

1 HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	10.00	8.50	7.00	5.00	3.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	9.30	7.94	6.43	4.68	2.80	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 3	8.70	7.38	5.88	4.17	2.36	.76	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 4	8.20	6.85	5.29	3.46	1.31	.44	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 5	7.70	6.34	4.73	2.59	-2.64	-.42	-.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 6	7.20	5.88	4.36	2.58	.52	.09	-.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 7	6.70	5.43	4.01	2.44	.91	.23	.01	-.03	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 8	6.20	4.97	3.58	1.98	.26	-.13	-.18	-.12	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 9	5.70	4.51	3.12	1.29	-2.76	-.91	-.49	-.28	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 10	5.20	4.09	2.80	1.29	-.38	-.65	-.63	-.52	-.31	.00	.00	.00	.00	.00	.00	.00	.00
0 11	4.80	3.69	2.48	1.14	-.13	-.69	-.87	-.88	-.75	-.41	.00	.00	.00	.00	.00	.00	.00
0 12	4.30	3.27	2.09	.72	-.78	-1.16	-1.30	-1.41	-1.46	-.94	-.44	.00	.00	.00	.00	.00	.00
0 13	3.80	2.85	1.68	.11	-3.60	-1.97	-1.80	-2.06	-3.12	-1.57	-.86	-.36	.00	.00	.00	.00	.00
0 14	3.50	2.52	1.41	.12	-1.37	-1.71	-1.89	-2.10	-2.27	-1.72	-1.16	-.63	.00	.00	.00	.00	.00
0 15	3.10	2.18	1.16	.05	-1.04	-1.63	-1.97	-2.20	-2.26	-1.94	-1.51	-1.06	-.56	.00	.00	.00	.00
0 16	2.70	1.81	.84	-.23	-1.37	-1.84	-2.17	-2.47	-2.68	-2.32	-1.93	-1.61	-1.30	-.55	.00	.00	.00
0 17	2.20	1.40	.48	-.66	-2.66	-2.26	-2.43	-2.86	-3.95	-2.80	-2.36	-2.24	-2.83	-1.02	.00	.00	.00

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 18	1.70	.99	.19	-.74	-1.75	-2.15	-2.47	-2.81	-3.11	-2.81	-2.49	-2.25	-1.99	-1.14	-.42	.00	.00
0 19	1.20	.59	-.10	-.88	-1.66	-2.14	-2.51	-2.82	-3.02	-2.85	-2.58	-2.29	-1.91	-1.25	-.59	.00	.00
0 20	.70	.21	-.40	-1.14	-1.94	-2.30	-2.62	-2.97	-3.31	-3.01	-2.70	-2.45	-2.16	-1.43	-.78	-.27	.00
0 21	.20	-.13	-.67	-1.44	-2.82	-2.54	-2.72	-3.19	-4.50	-3.22	-2.80	-2.66	-3.01	-1.63	-.87	-.35	.00
0 22	.00	-.30	-.78	-1.40	-2.09	-2.35	-2.58	-2.88	-3.17	-2.90	-2.63	-2.42	-2.18	-1.46	-.80	-.28	.00
0 23	.00	-.33	-.79	-1.35	-1.92	-2.20	-2.40	-2.61	-2.75	-2.61	-2.42	-2.24	-1.96	-1.33	-.66	.00	.00
0 24	.00	-.26	-.75	-1.37	-2.07	-2.16	-2.24	-2.42	-2.64	-2.40	-2.22	-2.18	-2.15	-1.31	-.59	.00	.00
0 25	.00	.00	-.62	-1.38	-2.99	-2.11	-1.99	-2.20	-3.01	-2.14	-1.92	-2.10	-3.43	-1.29	-.45	.00	.00
0 26	.00	.00	-.42	-.90	-1.44	-1.44	-1.45	-1.53	-1.63	-1.40	-1.25	-1.19	-1.12	-.57	.00	.00	.00
0 27	.00	.00	-.22	-.45	-.74	-.85	-.89	-.91	-.86	-.69	-.57	-.42	.00	.00	.00	.00	.00
0 28	.00	.00	.00	.00	-.27	-.37	-.41	-.40	-.30	.00	.00	.00	.00	.00	.00	.00	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

1 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	2.90	2.90	2.80	2.80	2.80	2.70	2.70	2.70	2.60	2.60	2.60	2.50	2.50	2.50	2.40	2.40	2.40
0 2	2.90	2.74	2.55	2.40	2.29	2.24	2.25	2.28	2.28	2.31	2.32	2.32	2.33	2.34	2.33	2.35	2.40
0 3	2.90	2.60	2.27	1.96	1.73	1.72	1.80	1.88	1.95	2.02	2.07	2.12	2.16	2.21	2.24	2.28	2.30
0 4	2.90	2.47	1.98	1.44	.94	1.12	1.33	1.50	1.63	1.74	1.83	1.92	2.00	2.08	2.15	2.23	2.30
0 5	3.00	2.39	1.73	.89	-.52	.48	.91	1.15	1.33	1.48	1.61	1.73	1.84	1.95	2.06	2.18	2.30
0 6	3.10	2.37	1.64	.92	.29	.43	.66	.87	1.06	1.23	1.39	1.54	1.68	1.83	1.97	2.12	2.30
0 7	3.10	2.33	1.57	.85	.32	.28	.43	.62	.82	1.00	1.18	1.35	1.53	1.70	1.88	2.05	2.20
0 8	3.10	2.28	1.44	.59	-.13	-.05	.16	.37	.58	.78	.97	1.17	1.38	1.58	1.79	1.99	2.20
0 9	3.20	2.26	1.30	.22	-1.39	-.50	-.12	.13	.34	.55	.77	.99	1.22	1.46	1.70	1.94	2.20
0 10	3.20	2.26	1.30	.36	-.45	-.43	-.28	-.09	.11	.33	.56	.80	1.06	1.32	1.60	1.89	2.20
0 11	3.30	2.27	1.28	.36	-.34	-.51	-.46	-.31	-.13	.09	.34	.60	.89	1.19	1.49	1.81	2.10
0 12	3.30	2.25	1.18	.14	-.76	-.82	-.72	-.58	-.40	-.17	.09	.38	.70	1.04	1.39	1.74	2.10
0 13	3.40	2.24	1.07	-.22	-2.01	-1.28	-1.04	-.89	-.71	-.48	-.19	.14	.50	.88	1.27	1.68	2.10
0 14	3.40	2.24	1.06	-.08	-1.08	-1.25	-1.26	-1.22	-1.09	-.84	-.51	-.13	.28	.70	1.15	1.61	2.10
0 15	3.50	2.24	1.04	-.09	-.99	-1.38	-1.55	-1.62	-1.58	-1.28	-.87	-.43	.04	.51	1.00	1.50	2.00
0 16	3.50	2.20	.93	-.31	-1.42	-1.73	-1.93	-2.15	-2.33	-1.82	-1.27	-.74	-.22	.31	.85	1.39	1.90
0 17	3.40	2.12	.80	-.66	-2.66	-2.18	-2.29	-2.72	-3.77	-2.42	-1.65	-1.04	-.48	.10	.70	1.30	1.90
0 18	3.40	2.09	.80	-.49	-1.66	-2.05	-2.34	-2.66	-2.91	-2.42	-1.86	-1.31	-.75	-.12	.54	1.22	1.90
0 19	3.30	2.05	.79	-.42	-1.45	-2.00	-2.37	-2.66	-2.80	-2.50	-2.06	-1.60	-1.09	-.39	.37	1.13	1.90
0 20	3.30	2.02	.74	-.55	-1.73	-2.14	-2.47	-2.83	-3.13	-2.71	-2.27	-1.93	-1.62	-.70	.20	1.03	1.80
0 21	3.30	2.01	.69	-.77	-2.78	-2.35	-2.53	-3.04	-4.19	-2.95	-2.39	-2.22	-2.76	-1.00	.10	.99	1.80
0 22	3.20	2.01	.79	-.44	-1.58	-1.96	-2.26	-2.62	-2.93	-2.53	-2.11	-1.79	-1.52	-.64	.22	1.02	1.80
0 23	3.20	2.05	.90	-.21	-1.14	-1.62	-1.95	-2.24	-2.39	-2.12	-1.72	-1.32	-.88	-.26	.41	1.07	1.70
0 24	3.20	2.08	.97	-.14	-1.16	-1.45	-1.69	-1.99	-2.27	-1.83	-1.34	-.89	-.43	.08	.61	1.16	1.70
0 25	3.10	2.09	1.05	-.15	-1.92	-1.31	-1.36	-1.77	-2.87	-1.59	-.93	-.46	-.04	.38	.81	1.24	1.70
0 26	3.10	2.13	1.27	.42	-.38	-.51	-.65	-.88	-1.13	-.74	-.33	.03	.36	.68	1.00	1.31	1.60
0 27	2.70	2.07	1.49	.95	.50	.29	.15	.02	-.05	.10	.32	.55	.77	.98	1.19	1.40	1.60
0 28	2.30	1.96	1.66	1.39	1.15	1.02	.93	.87	.82	.87	.97	1.07	1.18	1.29	1.40	1.50	1.60
0 29	1.80	1.80	1.80	1.80	1.70	1.70	1.70	1.70	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60

OHEAD WILL BE SAVED ON UNIT 30 AT END OF TIME STEP 1, STRESS PERIOD 1

1 DRAWDOWN IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	.00	.23	.42	.56	.57	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 3	.00	.42	.81	1.18	1.39	.97	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 4	.00	.60	1.23	1.93	2.73	1.91	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 5	.00	.76	1.61	2.81	6.92	3.35	1.47	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 6	.00	.86	1.78	2.79	3.92	3.22	1.93	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 7	.00	.96	1.91	2.87	3.63	3.37	2.46	1.17	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 8	.00	1.05	2.12	3.25	4.34	3.94	3.00	1.71	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 9	.00	1.15	2.35	3.84	7.39	4.88	3.60	2.21	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 10	.00	1.22	2.44	3.73	5.03	4.77	4.05	3.01	1.60	.00	.00	.00	.00	.00	.00	.00	.00
0 11	.00	1.29	2.53	3.76	4.78	4.94	4.57	3.87	2.87	1.55	.00	.00	.00	.00	.00	.00	.00
0 12	.00	1.36	2.69	4.06	5.42	5.52	5.24	4.81	4.18	2.88	1.47	.00	.00	.00	.00	.00	.00
0 13	.00	1.44	2.88	4.54	8.21	6.40	5.93	5.77	6.29	4.09	2.62	1.24	.00	.00	.00	.00	.00
0 14	.00	1.48	2.93	4.40	5.93	6.18	6.15	6.04	5.77	4.68	3.43	2.01	.00	.00	.00	.00	.00
0 15	.00	1.52	2.95	4.32	5.53	6.11	6.32	6.31	6.02	5.23	4.21	3.02	1.57	.00	.00	.00	.00
0 16	.00	1.57	3.03	4.43	5.76	6.29	6.56	6.69	6.62	5.87	4.98	4.03	2.96	1.37	.00	.00	.00
0 17	.00	1.62	3.13	4.68	6.93	6.65	6.82	7.14	8.01	6.53	5.66	4.99	4.91	2.25	.00	.00	.00
0 18	.00	1.66	3.14	4.55	5.88	6.45	6.82	7.10	7.23	6.66	5.96	5.24	4.38	2.80	1.21	.00	.00
0 19	.00	1.69	3.15	4.47	5.62	6.32	6.78	7.07	7.14	6.74	6.14	5.42	4.51	3.19	1.71	.00	.00
0 20	.00	1.70	3.16	4.49	5.70	6.32	6.76	7.12	7.37	6.88	6.28	5.64	4.86	3.54	2.19	.89	.00
0 21	.00	1.70	3.15	4.55	6.36	6.36	6.69	7.20	8.44	6.99	6.31	5.82	5.71	3.78	2.36	1.11	.00
0 22	.00	1.61	2.99	4.25	5.39	5.94	6.34	6.69	6.93	6.51	5.99	5.45	4.77	3.51	2.19	.90	.00
0 23	.00	1.42	2.72	3.91	4.93	5.51	5.89	6.15	6.25	5.97	5.55	5.05	4.35	3.17	1.78	.00	.00
0 24	.00	1.02	2.34	3.60	4.75	5.14	5.39	5.63	5.80	5.42	5.02	4.67	4.23	2.87	1.49	.00	.00
0 25	.00	.00	1.77	3.22	5.28	4.69	4.74	4.99	5.74	4.72	4.27	4.14	5.07	2.47	1.05	.00	.00
0 26	.00	.00	1.26	2.32	3.28	3.55	3.70	3.81	3.82	3.40	3.02	2.64	2.13	1.20	.00	.00	.00
0 27	.00	.00	.72	1.33	2.02	2.39	2.54	2.56	2.36	1.91	1.57	1.12	.00	.00	.00	.00	.00
0 28	.00	.00	.00	.00	.88	1.22	1.34	1.29	.98	.00	.00	.00	.00	.00	.00	.00	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

1 DRAWDOWN IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	.00	.14	.29	.42	.50	.50	.45	.39	.34	.28	.24	.19	.16	.12	.08	.04	.00
0 3	.00	.29	.59	.87	1.06	1.03	.91	.79	.68	.57	.48	.39	.31	.22	.15	.08	.00
0 4	.00	.44	.91	1.41	1.87	1.64	1.39	1.17	1.00	.84	.71	.58	.46	.34	.23	.11	.00
0 5	.00	.57	1.19	1.99	3.35	2.30	1.82	1.53	1.30	1.10	.92	.76	.60	.45	.30	.15	.00
0 6	.00	.65	1.32	1.98	2.56	2.36	2.08	1.81	1.57	1.35	1.14	.94	.75	.56	.38	.19	.00
0 7	.00	.71	1.41	2.08	2.55	2.53	2.31	2.07	1.81	1.57	1.34	1.12	.89	.67	.44	.22	.00
0 8	.00	.79	1.57	2.36	3.01	2.87	2.59	2.32	2.05	1.79	1.54	1.28	1.02	.77	.51	.26	.00
0 9	.00	.85	1.74	2.75	4.29	3.33	2.88	2.56	2.29	2.01	1.73	1.45	1.17	.87	.58	.30	.00
0 10	.00	.89	1.77	2.64	3.37	3.27	3.05	2.78	2.51	2.23	1.93	1.63	1.31	1.00	.66	.33	.00
0 11	.00	.92	1.82	2.66	3.27	3.36	3.23	3.00	2.75	2.46	2.14	1.81	1.46	1.10	.75	.37	.00
0 12	.00	.97	1.95	2.90	3.70	3.68	3.49	3.27	3.01	2.71	2.38	2.02	1.63	1.23	.82	.42	.00
0 13	.00	1.03	2.09	3.27	4.96	4.14	3.81	3.57	3.31	3.00	2.64	2.24	1.81	1.37	.92	.46	.00
0 14	.00	1.05	2.11	3.14	4.03	4.11	4.02	3.89	3.68	3.35	2.94	2.49	2.01	1.52	1.01	.51	.00
0 15	.00	1.08	2.14	3.15	3.94	4.22	4.30	4.28	4.15	3.77	3.28	2.76	2.22	1.68	1.13	.56	.00
0 16	.00	1.12	2.25	3.36	4.35	4.56	4.66	4.78	4.88	4.28	3.65	3.04	2.45	1.85	1.24	.62	.00
0 17	.00	1.16	2.35	3.69	5.57	4.98	4.99	5.33	6.29	4.85	4.00	3.31	2.68	2.03	1.35	.68	.00
0 18	.00	1.16	2.32	3.48	4.54	4.82	5.01	5.23	5.39	4.82	4.18	3.55	2.91	2.21	1.48	.74	.00
0 19	.00	1.15	2.29	3.37	4.29	4.73	5.00	5.19	5.24	4.86	4.34	3.80	3.22	2.45	1.62	.80	.00
0 20	.00	1.15	2.29	3.46	4.52	4.82	5.05	5.31	5.52	5.02	4.50	4.09	3.71	2.72	1.75	.86	.00
0 21	.00	1.12	2.30	3.63	5.52	4.97	5.05	5.47	6.53	5.21	4.57	4.33	4.80	2.98	1.82	.87	.00
0 22	.00	1.06	2.14	3.23	4.25	4.52	4.72	4.98	5.21	4.73	4.24	3.85	3.52	2.58	1.66	.81	.00
0 23	.00	.98	1.97	2.93	3.73	4.10	4.33	4.53	4.60	4.26	3.79	3.33	2.83	2.15	1.42	.71	.00
0 24	.00	.89	1.82	2.77	3.66	3.84	3.98	4.20	4.40	3.89	3.34	2.84	2.32	1.76	1.18	.59	.00
0 25	.00	.78	1.62	2.67	4.31	3.59	3.55	3.88	4.92	3.58	2.86	2.34	1.88	1.41	.94	.48	.00
0 26	.00	.61	1.26	1.95	2.63	2.67	2.73	2.89	3.08	2.64	2.19	1.78	1.42	1.06	.71	.35	.00
0 27	.00	.41	.83	1.34	1.59	1.73	1.81	1.88	1.90	1.71	1.45	1.19	.95	.71	.48	.24	.00
0 28	.00	.20	.41	.60	.76	.85	.90	.92	.92	.84	.72	.60	.48	.36	.23	.12	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

0DRAWDOWN WILL BE SAVED ON UNIT 40 AT END OF TIME STEP 1, STRESS PERIOD 1

0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 1

	CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
0	IN:		IN:	
	STORAGE =	.00000	STORAGE =	.00000
	CONSTANT HEAD =	.84495E+07	CONSTANT HEAD =	4629.8
	WELLS =	.00000	WELLS =	.00000
0	TOTAL IN =	.84495E+07	TOTAL IN =	4629.8
0	OUT:		OUT:	
	STORAGE =	.00000	STORAGE =	.00000
	CONSTANT HEAD =	.45639E+06	CONSTANT HEAD =	250.08
	WELLS =	.79931E+07	WELLS =	4379.8
0	TOTAL OUT =	.84495E+07	TOTAL OUT =	4629.9

0 IN - OUT = -56.000 IN - OUT = -.30762E-01
0 PERCENT DISCREPANCY = .00 PERCENT DISCREPANCY = .00

0

TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
STRESS PERIOD TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
TOTAL SIMULATION TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658

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1                          U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
0NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY             SIM 3 - CAP, SHEET PILING SANFORD RD, S/D EXTRACT
     2 LAYERS         29 ROWS         17 COLUMNS
   1 STRESS PERIOD(S) IN SIMULATION
 MODEL TIME UNIT IS DAYS
0I/O UNITS:
 ELEMENT OF IUNIT:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
         I/O UNIT: 11 12  0  0  0  0  0  0 19  0  0 22  0  0  0  0  0  0  0  0  0  0  0  0
0BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT  1
 ARRAYS RHS AND BUFF WILL SHARE MEMORY.
 START HEAD WILL BE SAVED
     9421 ELEMENTS IN X ARRAY ARE USED BY BAS
     9421 ELEMENTS OF X ARRAY USED OUT OF  100000
0BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 11
 STEADY-STATE SIMULATION
      LAYER  AQUIFER TYPE
      -------------------
         1         1
         2         0
      988 ELEMENTS IN X ARRAY ARE USED BY BCF
    10409 ELEMENTS OF X ARRAY USED OUT OF  100000
0WEL1 -- WELL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM 12
 MAXIMUM OF    23 WELLS
       92 ELEMENTS IN X ARRAY ARE USED FOR WELLS
    10501 ELEMENTS OF X ARRAY USED OUT OF  100000
0SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 19
 MAXIMUM OF  50 ITERATIONS ALLOWED FOR CLOSURE
  5 ITERATION PARAMETERS
     4149 ELEMENTS IN X ARRAY ARE USED BY SIP
    14650 ELEMENTS OF X ARRAY USED OUT OF  100000
1NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY             SIM 3 - CAP, SHEET PILING SANFORD RD, S/D EXTRACT
0
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BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 2	0	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 3	0	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 4	0	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 5	0	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 6	0	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 7	0	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 8	0	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 9	0	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 10	0	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
0 11	0	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1
0 12	0	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1
0 13	0	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
0 14	0	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
0 15	0	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1
0 16	0	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1
0 17	0	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1
0 18	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 19	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 20	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 21	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 22	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 23	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 24	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 25	0	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1
0 26	0	-1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1
0 27	0	-1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
0 28	0	-1	-1	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
0 29	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

0

BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
0 2	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 3	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 4	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 5	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 6	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 7	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 8	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 9	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 10	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 11	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 12	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 13	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2

0 14	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 15	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 16	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 17	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 18	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 19	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 20	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 21	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 22	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 23	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 24	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 25	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 26	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 27	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 28	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 29	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

0AQUIFER HEAD WILL BE SET TO -99.990 AT ALL NO-FLOW NODES (IBOUND=0).

0

INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	10.00	8.500	7.000	5.000	3.500	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 2	9.300	8.170	6.850	5.240	3.370	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 3	8.700	7.800	6.690	5.350	3.750	1.730	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 4	8.200	7.450	6.520	5.390	4.040	2.350	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 5	7.700	7.100	6.340	5.400	4.280	2.930	1.370	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 6	7.200	6.740	6.140	5.370	4.440	3.310	1.930	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 7	6.700	6.390	5.920	5.310	4.540	3.600	2.470	1.140	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 8	6.200	6.020	5.700	5.230	4.600	3.810	2.820	1.590	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 9	5.700	5.660	5.470	5.130	4.630	3.970	3.110	1.930	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 10	5.200	5.310	5.240	5.020	4.650	4.120	3.420	2.490	1.290	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 11	4.800	4.980	5.010	4.900	4.650	4.250	3.700	2.990	2.120	1.140	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 12	4.300	4.630	4.780	4.780	4.640	4.360	3.940	3.400	2.720	1.940	1.030	.0000	.0000	.0000	.0000	.0000	.0000
0 13	3.800	4.290	4.560	4.650	4.610	4.430	4.130	3.710	3.170	2.520	1.760	.8800	.0000	.0000	.0000	.0000	.0000
0 14	3.500	4.000	4.340	4.520	4.560	4.470	4.260	3.940	3.500	2.960	2.270	1.380	.0000	.0000	.0000	.0000	.0000
0 15	3.100	3.700	4.110	4.370	4.490	4.480	4.350	4.110	3.760	3.290	2.700	1.960	1.010	.0000	.0000	.0000	.0000
0 16	2.700	3.380	3.870	4.200	4.390	4.450	4.390	4.220	3.940	3.550	3.050	2.420	1.660	.8200	.0000	.0000	.0000
0 17	2.200	3.020	3.610	4.020	4.270	4.390	4.390	4.280	4.060	3.730	3.300	2.750	2.080	1.230	.0000	.0000	.0000
0 18	1.700	2.650	3.330	3.810	4.130	4.300	4.350	4.290	4.120	3.850	3.470	2.990	2.390	1.660	.7900	.0000	.0000
0 19	1.200	2.280	3.050	3.590	3.960	4.180	4.270	4.250	4.120	3.890	3.560	3.130	2.600	1.940	1.120	.0000	.0000
0 20	.7000	1.910	2.760	3.350	3.760	4.020	4.140	4.150	4.060	3.870	3.580	3.190	2.700	2.110	1.410	.6200	.0000
0 21	.2000	1.570	2.480	3.110	3.540	3.820	3.970	4.010	3.940	3.770	3.510	3.160	2.700	2.150	1.490	.7600	.0000
0 22	.0000	1.310	2.210	2.850	3.300	3.590	3.760	3.810	3.760	3.610	3.360	3.030	2.590	2.050	1.390	.6200	.0000
0 23	.0000	1.090	1.930	2.560	3.010	3.310	3.490	3.540	3.500	3.360	3.130	2.810	2.390	1.840	1.120	.0000	.0000
0 24	.0000	.7600	1.590	2.230	2.680	2.980	3.150	3.210	3.160	3.020	2.800	2.490	2.080	1.560	.9000	.0000	.0000
0 25	.0000	.0000	1.150	1.840	2.290	2.580	2.750	2.790	2.730	2.580	2.350	2.040	1.640	1.180	.6000	.0000	.0000
0 26	.0000	.0000	.8400	1.420	1.840	2.110	2.250	2.280	2.190	2.000	1.770	1.450	1.010	.6300	.0000	.0000	.0000
0 27	.0000	.0000	.5000	.8800	1.280	1.540	1.650	1.650	1.500	1.220	1.000	.7000	.0000	.0000	.0000	.0000	.0000
0 28	.0000	.0000	.0000	.0000	.6100	.8500	.9300	.8900	.6800	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 29	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

0

INITIAL HEAD FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	2.900	2.900	2.800	2.800	2.800	2.700	2.700	2.700	2.600	2.600	2.600	2.500	2.500	2.500	2.400	2.400	2.400
0 2	2.900	2.880	2.840	2.820	2.790	2.740	2.700	2.670	2.620	2.590	2.560	2.510	2.490	2.460	2.410	2.390	2.400
0 3	2.900	2.890	2.860	2.830	2.790	2.750	2.710	2.670	2.630	2.590	2.550	2.510	2.470	2.430	2.390	2.360	2.300
0 4	2.900	2.910	2.890	2.850	2.810	2.760	2.720	2.670	2.630	2.580	2.540	2.500	2.460	2.420	2.380	2.340	2.300
0 5	3.000	2.960	2.920	2.880	2.830	2.780	2.730	2.680	2.630	2.580	2.530	2.490	2.440	2.400	2.360	2.330	2.300
0 6	3.100	3.020	2.960	2.900	2.850	2.790	2.740	2.680	2.630	2.580	2.530	2.480	2.430	2.390	2.350	2.310	2.300
0 7	3.100	3.040	2.980	2.930	2.870	2.810	2.740	2.690	2.630	2.570	2.520	2.470	2.420	2.370	2.320	2.270	2.200
0 8	3.100	3.070	3.010	2.950	2.880	2.820	2.750	2.690	2.630	2.570	2.510	2.450	2.400	2.350	2.300	2.250	2.200
0 9	3.200	3.110	3.040	2.970	2.900	2.830	2.760	2.690	2.630	2.560	2.500	2.440	2.390	2.330	2.280	2.240	2.200
0 10	3.200	3.150	3.070	3.000	2.920	2.840	2.770	2.690	2.620	2.560	2.490	2.430	2.370	2.320	2.260	2.220	2.200
0 11	3.300	3.190	3.100	3.020	2.930	2.850	2.770	2.690	2.620	2.550	2.480	2.410	2.350	2.290	2.240	2.180	2.100
0 12	3.300	3.220	3.130	3.040	2.940	2.860	2.770	2.690	2.610	2.540	2.470	2.400	2.330	2.270	2.210	2.160	2.100
0 13	3.400	3.270	3.160	3.050	2.950	2.860	2.770	2.680	2.600	2.520	2.450	2.380	2.310	2.250	2.190	2.140	2.100
0 14	3.400	3.290	3.170	3.060	2.950	2.860	2.760	2.670	2.590	2.510	2.430	2.360	2.290	2.220	2.160	2.120	2.100
0 15	3.500	3.320	3.180	3.060	2.950	2.840	2.750	2.660	2.570	2.490	2.410	2.330	2.260	2.190	2.130	2.060	2.000
0 16	3.500	3.320	3.180	3.050	2.930	2.830	2.730	2.630	2.550	2.460	2.380	2.300	2.230	2.160	2.090	2.010	1.900
0 17	3.400	3.280	3.150	3.030	2.910	2.800	2.700	2.610	2.520	2.430	2.350	2.270	2.200	2.130	2.050	1.980	1.900
0 18	3.400	3.250	3.120	2.990	2.880	2.770	2.670	2.570	2.480	2.400	2.320	2.240	2.160	2.090	2.020	1.960	1.900
0 19	3.300	3.200	3.080	2.950	2.840	2.730	2.630	2.530	2.440	2.360	2.280	2.200	2.130	2.060	1.990	1.930	1.900
0 20	3.300	3.170	3.030	2.910	2.790	2.680	2.580	2.480	2.390	2.310	2.230	2.160	2.090	2.020	1.950	1.890	1.800
0 21	3.300	3.130	2.990	2.860	2.740	2.620	2.520	2.430	2.340	2.260	2.180	2.110	2.040	1.980	1.920	1.860	1.800
0 22	3.200	3.070	2.930	2.790	2.670	2.560	2.460	2.360	2.280	2.200	2.130	2.060	2.000	1.940	1.880	1.830	1.800
0 23	3.200	3.030	2.870	2.720	2.590	2.480	2.380	2.290	2.210	2.140	2.070	2.010	1.950	1.890	1.830	1.780	1.700
0 24	3.200	2.970	2.790	2.630	2.500	2.390	2.290	2.210	2.130	2.060	2.000	1.950	1.890	1.840	1.790	1.750	1.700
0 25	3.100	2.870	2.670	2.520	2.390	2.280	2.190	2.110	2.050	1.990	1.930	1.880	1.840	1.790	1.750	1.720	1.700
0 26	3.100	2.740	2.530	2.370	2.250	2.160	2.080	2.010	1.950	1.900	1.860	1.810	1.780	1.740	1.710	1.660	1.600
0 27	2.700	2.480	2.320	2.290	2.090	2.020	1.960	1.900	1.850	1.810	1.770	1.740	1.720	1.690	1.670	1.640	1.600
0 28	2.300	2.160	2.070	1.990	1.910	1.870	1.830	1.790	1.740	1.710	1.690	1.670	1.660	1.650	1.630	1.620	1.600
0 29	1.800	1.800	1.800	1.800	1.700	1.700	1.700	1.700	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600

```
OHEAD PRINT FORMAT IS FORMAT NUMBER   4    DRAWDOWN PRINT FORMAT IS FORMAT NUMBER   9
OHEADS WILL BE SAVED ON UNIT 30    DRAWDOWNS WILL BE SAVED ON UNIT 40
OOUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
0                                         COLUMN TO ROW ANISOTROPY =   1.000000
0                                                             DELR =   50.00000
0                                                             DELC =   50.00000
0                                      HYD. COND. ALONG ROWS =   6.500000     FOR LAYER  1
0                                                           BOTTOM =  -6.900000     FOR LAYER  1
0                                         VERT HYD COND /THICKNESS =   .1000000E-04 FOR LAYER  1
0                                           TRANSMIS. ALONG ROWS =   41.00000     FOR LAYER  2
0


                                          SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE
                                          -------------------------------------------
0                                    MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =        50
                                                   ACCELERATION PARAMETER =      1.0000
                                         HEAD CHANGE CRITERION FOR CLOSURE =     .10000E-02
                                         SIP HEAD CHANGE PRINTOUT INTERVAL =       1
0                                        CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED
1                                       STRESS PERIOD NO.    1, LENGTH =    1825.000
                                        ----------------------------------------------

                                        NUMBER OF TIME STEPS =      1

                                          MULTIPLIER FOR DELT =      1.000

                                      INITIAL TIME STEP SIZE =   1825.000
```

0 23 WELLS

LAYER	ROW	COL	STRESS RATE	WELL NO.
1	5	5	-336.90	1
1	9	5	-144.40	2
1	13	5	-48.100	3
1	13	9	-144.40	4
1	17	5	-48.100	5
1	17	9	-48.100	6
1	17	13	-192.50	7
1	21	5	-48.100	8
1	21	9	-48.100	9
1	21	13	-144.40	10
1	25	5	-144.40	11
1	25	9	-96.300	12
1	25	13	-192.50	13
2	5	5	-192.50	14
2	9	5	-192.50	15
2	13	5	-192.50	16
2	17	5	-192.50	17
2	17	9	-192.50	18
2	21	5	-192.50	19
2	21	9	-192.50	20
2	21	13	-192.50	21
2	25	5	-192.50	22
2	25	9	-192.50	23

0AVERAGE SEED = .00031905
MINIMUM SEED = .00016021
0
5 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

.0000000E+00 .8663512E+00 .9821380E+00 .9976128E+00 .9996809E+00

0
27 ITERATIONS FOR TIME STEP 1 IN STRESS PERIOD 1
0MAXIMUM HEAD CHANGE FOR EACH ITERATION:

0 HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL
-2.003	(1, 5, 5)	-1.665	(1, 6, 3)	-4.316	(1, 12, 5)	-2.088	(1, 17, 2)	-1.966	(1, 21, 5)
.6168	(1, 24, 2)	.3609	(1, 23, 3)	-.3435	(1, 12, 2)	-.4391	(1, 17, 5)	-.1250	(1, 17, 5)
-.6383E-01	(1, 13, 9)	.3306E-01	(1, 17, 3)	-.3242E-01	(1, 5, 5)	-.2583E-01	(1, 5, 5)	-.2036E-01	(1, 5, 5)
-.1780E-01	(1, 5, 5)	-.8895E-02	(1, 5, 5)	-.6234E-02	(1, 5, 5)	-.5232E-02	(1, 5, 5)	-.3609E-02	(1, 5, 5)
-.3925E-02	(1, 5, 5)	-.2179E-02	(1, 5, 5)	-.2035E-02	(1, 5, 5)	-.1616E-02	(1, 5, 5)	-.1386E-02	(1, 5, 5)
-.1313E-02	(1, 5, 5)	-.7649E-03	(1, 5, 5)						

0
0HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 1 CELL-BY-CELL FLOW TERM FLAG = 0
0OUTPUT FLAGS FOR EACH LAYER:

LAYER	HEAD PRINTOUT	DRAWDOWN PRINTOUT	HEAD SAVE	DRAWDOWN SAVE
1	1	1	1	1
2	1	1	1	1

1 HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	-99.99	8.50	7.00	5.00	3.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	-99.99	6.12	5.26	3.90	2.36	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 3	-99.99	4.25	3.66	2.65	1.45	.36	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 4	-99.99	2.67	2.19	1.29	.13	-.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 5	-99.99	1.34	.89	-.20	-3.95	-1.16	-.42	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 6	-99.99	.29	-.05	-.74	-1.67	-1.16	-.58	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 7	-99.99	-.55	-.79	-1.21	-1.56	-1.29	-.81	-.32	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 8	-99.99	-1.26	-1.45	-1.81	-2.13	-1.66	-1.08	-.53	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 9	-99.99	-1.85	-2.05	-2.55	-4.06	-2.23	-1.42	-.75	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 10	-99.99	-2.30	-2.43	-2.69	-2.93	-2.34	-1.73	-1.15	-.55	.00	.00	.00	.00	.00	.00	.00	.00
0 11	-99.99	-2.66	-2.74	-2.86	-2.88	-2.55	-2.12	-1.67	-1.17	-.58	.00	.00	.00	.00	.00	.00	.00
0 12	-99.99	-2.96	-3.03	-3.15	-3.21	-2.92	-2.60	-2.33	-2.05	-1.25	-.55	.00	.00	.00	.00	.00	.00
0 13	-99.99	-3.23	-3.31	-3.51	-4.05	-3.37	-3.11	-3.17	-4.26	-2.00	-1.08	-.45	.00	.00	.00	.00	.00
0 14	-99.99	-3.43	-3.50	-3.62	-3.75	-3.53	-3.35	-3.24	-3.12	-2.22	-1.46	-.77	.00	.00	.00	.00	.00
0 15	-99.99	-3.58	-3.64	-3.75	-3.82	-3.69	-3.52	-3.34	-3.07	-2.49	-1.89	-1.32	-.70	.00	.00	.00	.00
0 16	-99.99	-3.68	-3.76	-3.92	-4.10	-3.90	-3.72	-3.57	-3.38	-2.87	-2.40	-2.04	-1.67	-.69	.00	.00	.00

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 17	-99.99	-3.70	-3.81	-4.10	-4.93	-4.15	-3.90	-3.86	-4.19	-3.30	-2.92	-2.95	-4.34	-1.30	.00	.00	.00
0 18	-99.99	-3.62	-3.72	-3.92	-4.15	-4.02	-3.89	-3.83	-3.76	-3.39	-3.09	-2.89	-2.64	-1.45	-.52	.00	.00
0 19	-99.99	-3.45	-3.55	-3.73	-3.90	-3.89	-3.83	-3.79	-3.70	-3.44	-3.18	-2.90	-2.46	-1.58	-.74	.00	.00
0 20	-99.99	-3.20	-3.33	-3.56	-3.85	-3.81	-3.77	-3.79	-3.82	-3.53	-3.29	-3.12	-2.86	-1.82	-.97	-.34	.00
0 21	-99.99	-2.86	-3.02	-3.38	-4.18	-3.73	-3.66	-3.78	-4.32	-3.60	-3.35	-3.46	-4.73	-2.08	-1.08	-.42	.00
0 22	-99.99	-2.40	-2.59	-2.92	-3.30	-3.35	-3.37	-3.44	-3.51	-3.28	-3.09	-2.97	-2.77	-1.80	-.97	-.34	.00
0 23	-99.99	-1.82	-2.09	-2.50	-2.90	-3.02	-3.06	-3.12	-3.15	-2.98	-2.79	-2.62	-2.31	-1.55	-.77	.00	.00
0 24	-99.99	-1.06	-1.53	-2.15	-2.85	-2.80	-2.76	-2.85	-3.01	-2.71	-2.51	-2.45	-2.40	-1.46	-.65	.00	.00
0 25	-99.99	.00	-.94	-1.84	-3.69	-2.58	-2.37	-2.54	-3.35	-2.38	-2.11	-2.29	-3.66	-1.37	-.48	.00	.00
0 26	-99.99	.00	-.57	-1.14	-1.71	-1.71	-1.69	-1.74	-1.81	-1.54	-1.36	-1.28	-1.18	-.60	.00	.00	.00
0 27	-99.99	.00	-.27	-.55	-.87	-.99	-1.02	-1.02	-.96	-.75	-.62	-.45	.00	.00	.00	.00	.00
0 28	-99.99	.00	.00	.00	-.31	-.43	-.46	-.45	-.34	.00	.00	.00	.00	.00	.00	.00	.00
0 29	-99.99	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

1 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	2.90	2.90	2.80	2.80	2.80	2.70	2.70	2.70	2.60	2.60	2.60	2.50	2.50	2.50	2.40	2.40	2.40
0 2	2.90	2.74	2.55	2.40	2.29	2.24	2.25	2.28	2.28	2.30	2.32	2.32	2.33	2.34	2.33	2.35	2.40
0 3	2.90	2.59	2.27	1.96	1.72	1.72	1.79	1.88	1.95	2.01	2.07	2.12	2.16	2.20	2.24	2.28	2.30
0 4	2.90	2.46	1.97	1.44	.93	1.11	1.32	1.49	1.62	1.73	1.83	1.92	2.00	2.08	2.15	2.23	2.30
0 5	3.00	2.38	1.72	.88	-.53	.47	.90	1.14	1.32	1.47	1.60	1.72	1.84	1.95	2.06	2.18	2.30
0 6	3.10	2.36	1.63	.91	.27	.42	.65	.86	1.05	1.22	1.38	1.53	1.68	1.82	1.97	2.12	2.30
0 7	3.10	2.32	1.55	.84	.31	.27	.42	.61	.81	.99	1.17	1.35	1.52	1.70	1.88	2.05	2.20
0 8	3.10	2.27	1.42	.58	-.15	-.06	.14	.36	.57	.77	.97	1.17	1.37	1.58	1.78	1.99	2.20
0 9	3.20	2.25	1.29	.20	-1.41	-.52	-.14	.11	.33	.54	.76	.98	1.21	1.45	1.69	1.94	2.20
0 10	3.20	2.25	1.28	.34	-.47	-.45	-.29	-.10	.10	.32	.55	.79	1.05	1.32	1.60	1.89	2.20
0 11	3.30	2.26	1.26	.34	-.36	-.53	-.47	-.33	-.14	.08	.32	.59	.88	1.18	1.49	1.80	2.10
0 12	3.30	2.24	1.17	.12	-.78	-.84	-.74	-.60	-.41	-.19	.08	.37	.69	1.03	1.38	1.74	2.10
0 13	3.40	2.23	1.05	-.24	-2.03	-1.30	-1.06	-.91	-.73	-.49	-.20	.13	.49	.87	1.27	1.68	2.10
0 14	3.40	2.23	1.05	-.10	-1.10	-1.27	-1.28	-1.23	-1.10	-.85	-.52	-.14	.27	.70	1.14	1.60	2.10
0 15	3.50	2.23	1.02	-.11	-1.01	-1.40	-1.57	-1.64	-1.60	-1.29	-.88	-.44	.03	.51	1.00	1.50	2.00
0 16	3.50	2.19	.92	-.33	-1.44	-1.75	-1.95	-2.17	-2.35	-1.84	-1.28	-.75	-.23	.31	.84	1.38	1.90
0 17	3.40	2.11	.78	-.68	-2.68	-2.20	-2.31	-2.74	-3.78	-2.43	-1.66	-1.06	-.49	.09	.69	1.30	1.90
0 18	3.40	2.08	.78	-.50	-1.68	-2.06	-2.36	-2.68	-2.93	-2.44	-1.87	-1.32	-.76	-.13	.54	1.22	1.90
0 19	3.30	2.04	.78	-.44	-1.47	-2.02	-2.38	-2.68	-2.82	-2.51	-2.07	-1.61	-1.10	-.39	.37	1.13	1.90
0 20	3.30	2.02	.73	-.56	-1.74	-2.15	-2.48	-2.84	-3.15	-2.73	-2.28	-1.94	-1.63	-.71	.20	1.03	1.80
0 21	3.30	2.00	.68	-.78	-2.79	-2.36	-2.54	-3.05	-4.20	-2.97	-2.40	-2.23	-2.77	-1.01	.10	.99	1.80
0 22	3.20	2.01	.78	-.45	-1.59	-1.97	-2.28	-2.63	-2.94	-2.54	-2.12	-1.80	-1.53	-.64	.22	1.02	1.80
0 23	3.20	2.04	.89	-.21	-1.15	-1.63	-1.96	-2.25	-2.40	-2.13	-1.73	-1.33	-.89	-.26	.41	1.07	1.70
0 24	3.20	2.07	.97	-.14	-1.17	-1.45	-1.70	-2.00	-2.28	-1.84	-1.35	-.90	-.44	.07	.61	1.16	1.70
0 25	3.10	2.09	1.04	-.15	-1.93	-1.32	-1.36	-1.78	-2.87	-1.60	-.94	-.46	-.04	.38	.81	1.24	1.70
0 26	3.10	2.13	1.27	.42	-.38	-.52	-.66	-.89	-1.14	-.74	-.33	.03	.36	.68	1.00	1.31	1.60
0 27	2.70	2.07	1.49	.95	.50	.29	.15	.02	-.05	.10	.32	.55	.77	.98	1.19	1.40	1.60
0 28	2.30	1.96	1.66	1.39	1.15	1.02	.93	.87	.82	.87	.97	1.07	1.18	1.29	1.40	1.50	1.60
0 29	1.80	1.80	1.80	1.80	1.70	1.70	1.70	1.70	1.60	1.60	1.60	1.60	1.60	1.60	1.60		

1.60 1.60

OHEAD WILL BE SAVED ON UNIT 30 AT END OF TIME STEP 1, STRESS PERIOD 1

1 DRAWDOWN IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	*****	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	*****	2.05	1.59	1.34	1.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 3	*****	3.55	3.03	2.70	2.30	1.37	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 4	*****	4.78	4.33	4.10	3.91	2.49	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 5	*****	5.76	5.45	5.60	8.23	4.09	1.79	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 6	*****	6.45	6.19	6.11	6.11	4.47	2.51	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 7	*****	6.94	6.71	6.52	6.10	4.89	3.28	1.46	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 8	*****	7.28	7.15	7.04	6.73	5.47	3.90	2.12	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 9	*****	7.51	7.52	7.68	8.69	6.20	4.53	2.68	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 10	*****	7.61	7.67	7.71	7.58	6.46	5.15	3.64	1.84	.00	.00	.00	.00	.00	.00	.00	.00
0 11	*****	7.64	7.75	7.76	7.53	6.80	5.82	4.66	3.29	1.72	.00	.00	.00	.00	.00	.00	.00
0 12	*****	7.59	7.81	7.93	7.85	7.28	6.54	5.73	4.77	3.19	1.58	.00	.00	.00	.00	.00	.00
0 13	*****	7.52	7.87	8.16	8.66	7.80	7.24	6.88	7.43	4.52	2.84	1.33	.00	.00	.00	.00	.00
0 14	*****	7.43	7.84	8.14	8.31	8.00	7.61	7.18	6.62	5.18	3.73	2.15	.00	.00	.00	.00	.00
0 15	*****	7.28	7.75	8.12	8.31	8.17	7.87	7.45	6.83	5.78	4.59	3.28	1.71	.00	.00	.00	.00
0 16	*****	7.06	7.63	8.12	8.49	8.35	8.11	7.79	7.32	6.42	5.45	4.46	3.33	1.51	.00	.00	.00
0 17	*****	6.72	7.42	8.12	9.20	8.54	8.29	8.14	8.25	7.03	6.22	5.70	6.42	2.53	.00	.00	.00
0 18	*****	6.27	7.05	7.73	8.28	8.32	8.24	8.12	7.88	7.24	6.56	5.88	5.03	3.11	1.31	.00	.00
0 19	*****	5.73	6.60	7.32	7.86	8.07	8.10	8.04	7.82	7.33	6.74	6.03	5.06	3.52	1.86	.00	.00
0 20	*****	5.11	6.09	6.91	7.61	7.83	7.91	7.94	7.88	7.40	6.87	6.31	5.56	3.93	2.38	.96	.00
0 21	*****	4.43	5.50	6.49	7.72	7.55	7.63	7.79	8.26	7.37	6.86	6.62	7.43	4.23	2.57	1.18	.00
0 22	*****	3.71	4.80	5.77	6.60	6.94	7.13	7.25	7.27	6.89	6.45	6.00	5.36	3.85	2.36	.96	.00
0 23	*****	2.91	4.02	5.06	5.91	6.33	6.55	6.66	6.65	6.34	5.92	5.43	4.70	3.39	1.89	.00	.00
0 24	*****	1.82	3.12	4.38	5.53	5.78	5.91	6.06	6.17	5.73	5.31	4.94	4.48	3.02	1.55	.00	.00
0 25	*****	.00	2.09	3.68	5.98	5.16	5.12	5.33	6.08	4.96	4.46	4.33	5.30	2.55	1.08	.00	.00
0 26	*****	.00	1.41	2.56	3.55	3.82	3.94	4.02	4.00	3.54	3.13	2.73	2.19	1.23	.00	.00	.00
0 27	*****	.00	.77	1.43	2.15	2.53	2.67	2.67	2.46	1.97	1.62	1.15	.00	.00	.00	.00	.00
0 28	*****	.00	.00	.00	.92	1.28	1.39	1.34	1.02	.00	.00	.00	.00	.00	.00	.00	.00
0 29	*****	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

1 DRAWDOWN IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	.00	.14	.29	.42	.50	.50	.45	.39	.34	.29	.24	.19	.16	.12	.08	.04	.00
0 3	.00	.30	.59	.87	1.07	1.03	.92	.79	.68	.58	.48	.39	.31	.23	.15	.08	.00
0 4	.00	.45	.92	1.41	1.88	1.65	1.40	1.18	1.01	.85	.71	.58	.46	.34	.23	.11	.00
0 5	.00	.58	1.20	2.00	3.36	2.31	1.83	1.54	1.31	1.11	.93	.77	.60	.45	.30	.15	.00
0 6	.00	.66	1.33	1.99	2.58	2.37	2.09	1.82	1.58	1.36	1.15	.95	.75	.57	.38	.19	.00
0 7	.00	.72	1.43	2.09	2.56	2.54	2.32	2.08	1.82	1.58	1.35	1.12	.90	.67	.44	.22	.00
0 8	.00	.80	1.59	2.37	3.03	2.88	2.61	2.33	2.06	1.80	1.54	1.28	1.03	.77	.52	.26	.00
0 9	.00	.86	1.75	2.77	4.31	3.35	2.90	2.58	2.30	2.02	1.74	1.46	1.18	.88	.59	.30	.00
0 10	.00	.90	1.79	2.66	3.39	3.29	3.06	2.79	2.52	2.24	1.94	1.64	1.32	1.00	.66	.33	.00
0 11	.00	.93	1.84	2.68	3.29	3.38	3.24	3.02	2.76	2.47	2.16	1.82	1.47	1.11	.75	.38	.00
0 12	.00	.98	1.96	2.92	3.72	3.70	3.51	3.29	3.02	2.73	2.39	2.03	1.64	1.24	.83	.42	.00
0 13	.00	1.04	2.11	3.29	4.98	4.16	3.83	3.59	3.33	3.01	2.65	2.25	1.82	1.38	.92	.46	.00
0 14	.00	1.06	2.12	3.16	4.05	4.13	4.04	3.90	3.69	3.36	2.95	2.50	2.02	1.52	1.02	.52	.00
0 15	.00	1.09	2.16	3.17	3.96	4.24	4.32	4.30	4.17	3.78	3.29	2.77	2.23	1.68	1.13	.56	.00
0 16	.00	1.13	2.26	3.38	4.37	4.58	4.68	4.80	4.90	4.30	3.66	3.05	2.46	1.85	1.25	.63	.00
0 17	.00	1.17	2.37	3.71	5.59	5.00	5.01	5.35	6.30	4.86	4.01	3.33	2.69	2.04	1.36	.68	.00
0 18	.00	1.17	2.34	3.49	4.56	4.83	5.03	5.25	5.41	4.84	4.19	3.56	2.92	2.22	1.48	.74	.00
0 19	.00	1.16	2.30	3.39	4.31	4.75	5.01	5.21	5.26	4.87	4.35	3.81	3.23	2.45	1.62	.80	.00
0 20	.00	1.15	2.30	3.47	4.53	4.83	5.06	5.32	5.54	5.04	4.51	4.10	3.72	2.73	1.75	.86	.00
0 21	.00	1.13	2.31	3.64	5.53	4.98	5.06	5.48	6.54	5.23	4.58	4.34	4.81	2.99	1.82	.87	.00
0 22	.00	1.06	2.15	3.24	4.26	4.53	4.74	4.99	5.22	4.74	4.25	3.86	3.53	2.58	1.66	.81	.00
0 23	.00	.99	1.98	2.93	3.74	4.11	4.34	4.54	4.61	4.27	3.80	3.34	2.84	2.15	1.42	.71	.00
0 24	.00	.90	1.82	2.77	3.67	3.84	3.99	4.21	4.41	3.90	3.35	2.85	2.33	1.77	1.18	.59	.00
0 25	.00	.78	1.63	2.67	4.32	3.60	3.55	3.89	4.92	3.59	2.87	2.34	1.88	1.41	.94	.48	.00
0 26	.00	.61	1.26	1.95	2.63	2.68	2.74	2.90	3.09	2.64	2.19	1.78	1.42	1.06	.71	.35	.00
0 27	.00	.41	.83	1.34	1.59	1.73	1.81	1.88	1.90	1.71	1.45	1.19	.95	.71	.48	.24	.00
0 28	.00	.20	.41	.60	.76	.85	.90	.92	.92	.84	.72	.60	.48	.36	.23	.12	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

0DRAWDOWN WILL BE SAVED ON UNIT 40 AT END OF TIME STEP 1, STRESS PERIOD 1

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VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 1

	CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
0	IN:		IN:	
	STORAGE =	.00000	STORAGE =	.00000
	CONSTANT HEAD =	.68007E+07	CONSTANT HEAD =	3726.4
	WELLS =	.00000	WELLS =	.00000
0	TOTAL IN =	.68007E+07	TOTAL IN =	3726.4
0	OUT:		OUT:	
	STORAGE =	.00000	STORAGE =	.00000
	CONSTANT HEAD =	.30132E+06	CONSTANT HEAD =	165.11

0
0
0

WELLS =	.64994E+07	WELLS =	3561.3
TOTAL OUT =	.68007E+07	TOTAL OUT =	3726.4
IN - OUT =	-8.5000	IN - OUT =	-.48828E-02
PERCENT DISCREPANCY =	.00	PERCENT DISCREPANCY =	.00

0

TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
STRESS PERIOD TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
TOTAL SIMULATION TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658

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1                    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
0NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY             SIM 4 - CAP, SHEET PILING SURROUNDING, S/D EXTRACT
    2 LAYERS         29 ROWS         17 COLUMNS
   1 STRESS PERIOD(S) IN SIMULATION
 MODEL TIME UNIT IS DAYS
0I/O UNITS:
 ELEMENT OF IUNIT:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
         I/O UNIT: 11 12  0  0  0  0  0  0 19  0  0 22  0  0  0  0  0  0  0  0  0  0  0  0
0BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT  1
 ARRAYS RHS AND BUFF WILL SHARE MEMORY.
 START HEAD WILL BE SAVED
     9421 ELEMENTS IN X ARRAY ARE USED BY BAS
     9421 ELEMENTS OF X ARRAY USED OUT OF  100000
0BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 11
 TRANSIENT SIMULATION
      LAYER  AQUIFER TYPE
      -------------------
         1          1
         2          0
     1974 ELEMENTS IN X ARRAY ARE USED BY BCF
    11395 ELEMENTS OF X ARRAY USED OUT OF  100000
0WEL1 -- WELL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM 12
 MAXIMUM OF    23 WELLS
       92 ELEMENTS IN X ARRAY ARE USED FOR WELLS
    11487 ELEMENTS OF X ARRAY USED OUT OF  100000
0SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 19
 MAXIMUM OF  50 ITERATIONS ALLOWED FOR CLOSURE
  5 ITERATION PARAMETERS
     4149 ELEMENTS IN X ARRAY ARE USED BY SIP
    15636 ELEMENTS OF X ARRAY USED OUT OF  100000
1NCBC DAVISVILLE SITE 09, ALLEN HARBOR LANDFILL - FEASIBILITY STUDY             SIM 4 - CAP, SHEET PILING SURROUNDING, S/D EXTRACT
0
```

BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0 2	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0 3	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
0 4	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
0 5	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
0 6	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
0 7	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
0 8	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
0 9	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
0 10	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0 11	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 12	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0 13	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
0 14	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
0 15	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
0 16	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0 17	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0 18	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
0 19	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
0 20	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
0 21	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
0 22	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
0 23	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
0 24	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
0 25	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
0 26	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0 27	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
0 28	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0
0 29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0

BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (17I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
0 2	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 3	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 4	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 5	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 6	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 7	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 8	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 9	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 10	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 11	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 12	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 13	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2

0 14	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 15	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 16	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 17	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 18	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 19	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 20	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 21	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 22	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 23	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 24	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 25	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 26	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 27	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 28	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 29	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

0AQUIFER HEAD WILL BE SET TO -99.990 AT ALL NO-FLOW NODES (IBOUND=0).

0

INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	10.00	8.500	7.000	5.000	3.500	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 2	9.300	8.170	6.850	5.240	3.370	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 3	8.700	7.800	6.690	5.350	3.750	1.730	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 4	8.200	7.450	6.520	5.390	4.040	2.350	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 5	7.700	7.100	6.340	5.400	4.280	2.930	1.370	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 6	7.200	6.740	6.140	5.370	4.440	3.310	1.930	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 7	6.700	6.390	5.920	5.310	4.540	3.600	2.470	1.140	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 8	6.200	6.020	5.700	5.230	4.600	3.810	2.820	1.590	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 9	5.700	5.660	5.470	5.130	4.630	3.970	3.110	1.930	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 10	5.200	5.310	5.240	5.020	4.650	4.120	3.420	2.490	1.290	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 11	4.800	4.980	5.010	4.900	4.650	4.250	3.700	2.990	2.120	1.140	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 12	4.300	4.630	4.780	4.780	4.640	4.360	3.940	3.400	2.720	1.940	1.030	.0000	.0000	.0000	.0000	.0000	.0000
0 13	3.800	4.290	4.560	4.650	4.610	4.430	4.130	3.710	3.170	2.520	1.760	.8800	.0000	.0000	.0000	.0000	.0000
0 14	3.500	4.000	4.340	4.520	4.560	4.470	4.260	3.940	3.500	2.960	2.270	1.380	.0000	.0000	.0000	.0000	.0000
0 15	3.100	3.700	4.110	4.370	4.490	4.480	4.350	4.110	3.760	3.290	2.700	1.960	1.010	.0000	.0000	.0000	.0000
0 16	2.700	3.380	3.870	4.200	4.390	4.450	4.390	4.220	3.940	3.550	3.050	2.420	1.660	.8200	.0000	.0000	.0000
0 17	2.200	3.020	3.610	4.020	4.270	4.390	4.390	4.280	4.060	3.730	3.300	2.750	2.080	1.230	.0000	.0000	.0000
0 18	1.700	2.650	3.330	3.810	4.130	4.300	4.350	4.290	4.120	3.850	3.470	2.990	2.390	1.660	.7900	.0000	.0000
0 19	1.200	2.280	3.050	3.590	3.960	4.180	4.270	4.250	4.120	3.890	3.560	3.130	2.600	1.940	1.120	.0000	.0000
0 20	.7000	1.910	2.760	3.350	3.760	4.020	4.140	4.150	4.060	3.870	3.580	3.190	2.700	2.110	1.410	.6200	.0000
0 21	.2000	1.570	2.480	3.110	3.540	3.820	3.970	4.010	3.940	3.770	3.510	3.160	2.700	2.150	1.490	.7600	.0000
0 22	.0000	1.310	2.210	2.850	3.300	3.590	3.760	3.810	3.760	3.610	3.360	3.030	2.590	2.050	1.390	.6200	.0000
0 23	.0000	1.090	1.930	2.560	3.010	3.310	3.490	3.540	3.500	3.360	3.130	2.810	2.390	1.840	1.120	.0000	.0000
0 24	.0000	.7600	1.590	2.230	2.680	2.980	3.150	3.210	3.160	3.020	2.800	2.490	2.080	1.560	.9000	.0000	.0000
0 25	.0000	.0000	1.150	1.840	2.290	2.580	2.750	2.790	2.730	2.580	2.350	2.040	1.640	1.180	.6000	.0000	.0000
0 26	.0000	.0000	.8400	1.420	1.840	2.110	2.250	2.280	2.190	2.000	1.770	1.450	1.010	.6300	.0000	.0000	.0000
0 27	.0000	.0000	.5000	.8800	1.280	1.540	1.650	1.650	1.500	1.220	1.000	.7000	.0000	.0000	.0000	.0000	.0000
0 28	.0000	.0000	.0000	.0000	.6100	.8500	.9300	.8900	.6800	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0 29	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

0

INITIAL HEAD FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	2.900	2.900	2.800	2.800	2.800	2.700	2.700	2.700	2.600	2.600	2.600	2.500	2.500	2.500	2.400	2.400	2.400
0 2	2.900	2.880	2.840	2.820	2.790	2.740	2.700	2.670	2.620	2.590	2.560	2.510	2.490	2.460	2.410	2.390	2.400
0 3	2.900	2.890	2.860	2.830	2.790	2.750	2.710	2.670	2.630	2.590	2.550	2.510	2.470	2.430	2.390	2.360	2.300
0 4	2.900	2.910	2.890	2.850	2.810	2.760	2.720	2.670	2.630	2.580	2.540	2.500	2.460	2.420	2.380	2.340	2.300
0 5	3.000	2.960	2.920	2.880	2.830	2.780	2.730	2.680	2.630	2.580	2.530	2.490	2.440	2.400	2.360	2.330	2.300
0 6	3.100	3.020	2.960	2.900	2.850	2.790	2.740	2.680	2.630	2.580	2.530	2.480	2.430	2.390	2.350	2.310	2.300
0 7	3.100	3.040	2.980	2.930	2.870	2.810	2.740	2.690	2.630	2.570	2.520	2.470	2.420	2.370	2.320	2.270	2.200
0 8	3.100	3.070	3.010	2.950	2.880	2.820	2.750	2.690	2.630	2.570	2.510	2.450	2.400	2.350	2.300	2.250	2.200
0 9	3.200	3.110	3.040	2.970	2.900	2.830	2.760	2.690	2.630	2.560	2.500	2.440	2.390	2.330	2.280	2.240	2.200
0 10	3.200	3.150	3.070	3.000	2.920	2.840	2.770	2.690	2.620	2.560	2.490	2.430	2.370	2.320	2.260	2.220	2.200
0 11	3.300	3.190	3.100	3.020	2.930	2.850	2.770	2.690	2.620	2.550	2.480	2.410	2.350	2.290	2.240	2.180	2.100
0 12	3.300	3.220	3.130	3.040	2.940	2.860	2.770	2.690	2.610	2.540	2.470	2.400	2.330	2.270	2.210	2.160	2.100
0 13	3.400	3.270	3.160	3.050	2.950	2.860	2.770	2.680	2.600	2.520	2.450	2.380	2.310	2.250	2.190	2.140	2.100
0 14	3.400	3.290	3.170	3.060	2.950	2.860	2.760	2.670	2.590	2.510	2.430	2.360	2.290	2.220	2.160	2.120	2.100
0 15	3.500	3.320	3.180	3.060	2.950	2.840	2.750	2.660	2.570	2.490	2.410	2.330	2.260	2.190	2.130	2.060	2.000
0 16	3.500	3.320	3.180	3.050	2.930	2.830	2.730	2.630	2.550	2.460	2.380	2.300	2.230	2.160	2.090	2.010	1.900
0 17	3.400	3.280	3.150	3.030	2.910	2.800	2.700	2.610	2.520	2.430	2.350	2.270	2.200	2.130	2.050	1.980	1.900
0 18	3.400	3.250	3.120	2.990	2.880	2.770	2.670	2.570	2.480	2.400	2.320	2.240	2.160	2.090	2.020	1.960	1.900
0 19	3.300	3.200	3.080	2.950	2.840	2.730	2.630	2.530	2.440	2.360	2.280	2.200	2.130	2.060	1.990	1.930	1.900
0 20	3.300	3.170	3.030	2.910	2.790	2.680	2.580	2.480	2.390	2.310	2.230	2.160	2.090	2.020	1.950	1.890	1.800
0 21	3.300	3.130	2.990	2.860	2.740	2.620	2.520	2.430	2.340	2.260	2.180	2.110	2.040	1.980	1.920	1.860	1.800
0 22	3.200	3.070	2.930	2.790	2.670	2.560	2.460	2.360	2.280	2.200	2.130	2.060	2.000	1.940	1.880	1.830	1.800
0 23	3.200	3.030	2.870	2.720	2.590	2.480	2.380	2.290	2.210	2.140	2.070	2.010	1.950	1.890	1.830	1.780	1.700
0 24	3.200	2.970	2.790	2.630	2.500	2.390	2.290	2.210	2.130	2.060	2.000	1.950	1.890	1.840	1.790	1.750	1.700
0 25	3.100	2.870	2.670	2.520	2.390	2.280	2.190	2.110	2.050	1.990	1.930	1.880	1.840	1.790	1.750	1.720	1.700
0 26	3.100	2.740	2.530	2.370	2.250	2.160	2.080	2.010	1.950	1.900	1.860	1.810	1.780	1.740	1.710	1.660	1.600
0 27	2.700	2.480	2.320	2.290	2.090	2.020	1.960	1.900	1.850	1.810	1.770	1.740	1.720	1.690	1.670	1.640	1.600
0 28	2.300	2.160	2.070	1.990	1.910	1.870	1.830	1.790	1.740	1.710	1.690	1.670	1.660	1.650	1.630	1.620	1.600
0 29	1.800	1.800	1.800	1.800	1.700	1.700	1.700	1.700	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600

```
0HEAD PRINT FORMAT IS FORMAT NUMBER   4    DRAWDOWN PRINT FORMAT IS FORMAT NUMBER   9
0HEADS WILL BE SAVED ON UNIT 30    DRAWDOWNS WILL BE SAVED ON UNIT 40
0OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
0                                     COLUMN TO ROW ANISOTROPY =   1.000000
0                                                         DELR =   50.00000
0                                                         DELC =   50.00000
0                                         PRIMARY STORAGE COEF =   .1500000     FOR LAYER  1
0                                       HYD. COND. ALONG ROWS =    6.500000     FOR LAYER  1
0                                                       BOTTOM =  -6.900000     FOR LAYER  1
0                                   VERT HYD COND /THICKNESS =    .1000000E-04 FOR LAYER  1
0                                        PRIMARY STORAGE COEF =   .1000000E-01 FOR LAYER  2
0                                        TRANSMIS. ALONG ROWS =   41.00000     FOR LAYER  2
0

                           SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE
                           -------------------------------------------
0                 MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =        50
                               ACCELERATION PARAMETER =      1.0000
                     HEAD CHANGE CRITERION FOR CLOSURE =      .10000E-02
                     SIP HEAD CHANGE PRINTOUT INTERVAL =         1
0                    CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED
1                   STRESS PERIOD NO.    1, LENGTH =    370.0000
                    ---------------------------------------------

                    NUMBER OF TIME STEPS =      1

                     MULTIPLIER FOR DELT =      1.000
```

INITIAL TIME STEP SIZE = 370.0000

0 23 WELLS

LAYER	ROW	COL	STRESS RATE	WELL NO.
1	5	5	-192.50	1
1	9	5	-144.40	2
1	13	5	-144.40	3
1	13	9	-144.40	4
1	17	5	-144.40	5
1	17	9	-96.300	6
1	17	13	-96.300	7
1	21	5	-144.40	8
1	21	9	-96.300	9
1	21	13	-96.300	10
1	25	5	-96.300	11
1	25	9	-96.300	12
1	25	13	-96.300	13
2	5	5	-192.50	14
2	9	5	-192.50	15
2	13	5	-192.50	16
2	17	5	-192.50	17
2	17	9	-192.50	18
2	21	5	-192.50	19
2	21	9	-192.50	20
2	21	13	-192.50	21
2	25	5	-192.50	22
2	25	9	-192.50	23

0AVERAGE SEED = .00079473
MINIMUM SEED = .00016213
0
5 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

.0000000E+00 .8320982E+00 .9718090E+00 .9952667E+00 .9992053E+00

0
32 ITERATIONS FOR TIME STEP 1 IN STRESS PERIOD 1
0MAXIMUM HEAD CHANGE FOR EACH ITERATION:

HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL
2.806	(1, 3, 6)	-1.305	(1, 2, 3)	-2.361	(2, 19, 8)	-1.955	(1, 25, 2)	-3.388	(1, 3, 6)
-.6620	(1, 5, 5)	-.3380	(1, 22, 14)	-.7938	(1, 26, 14)	-.6138	(1, 15, 13)	-.4765	(1, 26, 14)
-.1964	(1, 21, 5)	-.1120	(1, 25, 13)	-.1592	(1, 17, 13)	-.1262	(1, 25, 13)	-.1047	(1, 13, 9)
-.7836E-01	(1, 13, 9)	-.3813E-01	(1, 13, 9)	-.2674E-01	(1, 25, 13)	-.2413E-01	(1, 13, 9)	-.1733E-01	(1, 13, 9)
-.1707E-01	(1, 13, 9)	-.9775E-02	(1, 13, 9)	-.8555E-02	(1, 13, 9)	-.6432E-02	(1, 13, 9)	-.5677E-02	(1, 13, 9)
-.5458E-02	(1, 13, 9)	-.3192E-02	(1, 13, 9)	-.2331E-02	(1, 13, 9)	-.2013E-02	(1, 13, 9)	-.1476E-02	(1, 13, 9)
-.1549E-02	(1, 13, 9)	-.9304E-03	(1, 13, 9)						

0
0HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 1 CELL-BY-CELL FLOW TERM FLAG = 0
0OUTPUT FLAGS FOR EACH LAYER:

LAYER	HEAD PRINTOUT	DRAWDOWN PRINTOUT	HEAD SAVE	DRAWDOWN SAVE
1	1	1	1	1
2	1	1	1	1

1 HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 2	-99.99	-.52	-.65	-.86	-1.05	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 3	-99.99	-.60	-.76	-1.05	-1.38	-1.61	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 4	-99.99	-.74	-.96	-1.39	-2.00	-1.96	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 5	-99.99	-.88	-1.15	-1.85	-4.18	-2.44	-2.16	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 6	-99.99	-.96	-1.19	-1.65	-2.27	-2.12	-2.01	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 7	-99.99	-1.03	-1.22	-1.56	-1.93	-1.94	-1.88	-1.81	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 8	-99.99	-1.11	-1.30	-1.68	-2.16	-2.03	-1.90	-1.84	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 9	-99.99	-1.20	-1.42	-1.96	-3.49	-2.30	-1.99	-1.91	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 10	-99.99	-1.26	-1.44	-1.80	-2.26	-2.12	-2.02	-2.04	-2.15	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 11	-99.99	-1.33	-1.48	-1.77	-2.08	-2.11	-2.12	-2.22	-2.39	-2.48	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 12	-99.99	-1.42	-1.60	-1.95	-2.43	-2.33	-2.32	-2.52	-2.90	-2.71	-2.60	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 13	-99.99	-1.52	-1.73	-2.28	-3.99	-2.70	-2.53	-2.92	-5.05	-3.04	-2.64	-2.51	-99.99	-99.99	-99.99	-99.99	-99.99
0 14	-99.99	-1.59	-1.76	-2.11	-2.60	-2.47	-2.45	-2.66	-3.03	-2.75	-2.57	-2.52	-99.99	-99.99	-99.99	-99.99	-99.99
0 15	-99.99	-1.66	-1.81	-2.08	-2.38	-2.38	-2.39	-2.52	-2.68	-2.61	-2.55	-2.61	-2.78	-99.99	-99.99	-99.99	-99.99

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 16	-99.99	-1.75	-1.91	-2.25	-2.71	-2.54	-2.46	-2.57	-2.82	-2.66	-2.62	-2.78	-3.11	-3.10	-99.99	-99.99	-99.99
0 17	-99.99	-1.85	-2.04	-2.58	-4.42	-2.86	-2.57	-2.76	-3.76	-2.84	-2.70	-2.99	-4.19	-3.26	-99.99	-99.99	-99.99
0 18	-99.99	-1.91	-2.06	-2.38	-2.82	-2.60	-2.48	-2.56	-2.78	-2.62	-2.59	-2.75	-3.03	-2.85	-2.65	-99.99	-99.99
0 19	-99.99	-1.96	-2.08	-2.33	-2.57	-2.51	-2.44	-2.48	-2.58	-2.53	-2.53	-2.63	-2.77	-2.68	-2.58	-99.99	-99.99
0 20	-99.99	-2.03	-2.17	-2.48	-2.90	-2.66	-2.52	-2.58	-2.78	-2.62	-2.57	-2.71	-2.94	-2.72	-2.54	-2.44	-99.99
0 21	-99.99	-2.09	-2.27	-2.78	-4.77	-2.97	-2.64	-2.80	-3.76	-2.83	-2.67	-2.91	-3.95	-2.90	-2.57	-2.45	-99.99
0 22	-99.99	-2.09	-2.22	-2.51	-2.91	-2.66	-2.53	-2.60	-2.81	-2.65	-2.61	-2.74	-2.97	-2.75	-2.57	-2.45	-99.99
0 23	-99.99	-2.09	-2.18	-2.37	-2.56	-2.50	-2.45	-2.51	-2.62	-2.58	-2.59	-2.69	-2.83	-2.74	-2.65	-99.99	-99.99
0 24	-99.99	-2.10	-2.19	-2.40	-2.67	-2.53	-2.47	-2.58	-2.82	-2.69	-2.67	-2.84	-3.12	-2.93	-2.79	-99.99	-99.99
0 25	-99.99	-2.11	-2.21	-2.54	-3.53	-2.67	-2.51	-2.75	-3.77	-2.89	-2.78	-3.10	-4.36	-3.26	-2.95	-99.99	-99.99
0 26	-99.99	-2.08	-2.15	-2.32	-2.55	-2.41	-2.37	-2.49	-2.74	-2.66	-2.69	-2.90	-3.37	-3.23	-99.99	-99.99	-99.99
0 27	-99.99	-2.06	-2.10	-2.19	-2.24	-2.22	-2.22	-2.29	-2.41	-2.50	-2.57	-2.67	-99.99	-99.99	-99.99	-99.99	-99.99
0 28	-99.99	-99.99	-99.99	-99.99	-2.14	-2.14	-2.15	-2.20	-2.25	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99
0 29	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99	-99.99

1 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	2.90	2.90	2.80	2.80	2.80	2.70	2.70	2.70	2.60	2.60	2.60	2.50	2.50	2.50	2.40	2.40	2.40
0 2	2.90	2.74	2.55	2.41	2.30	2.25	2.27	2.29	2.30	2.32	2.34	2.33	2.34	2.35	2.34	2.36	2.40
0 3	2.90	2.60	2.28	1.97	1.74	1.74	1.82	1.91	1.98	2.04	2.10	2.14	2.18	2.22	2.25	2.29	2.30
0 4	2.90	2.47	1.99	1.46	.97	1.15	1.36	1.53	1.67	1.78	1.87	1.95	2.03	2.10	2.17	2.24	2.30
0 5	3.00	2.40	1.74	.91	-.49	.52	.95	1.20	1.38	1.52	1.65	1.77	1.88	1.98	2.08	2.19	2.30
0 6	3.10	2.37	1.66	.95	.33	.48	.71	.93	1.12	1.29	1.44	1.59	1.73	1.86	2.00	2.14	2.30
0 7	3.10	2.34	1.59	.88	.37	.34	.49	.69	.88	1.07	1.24	1.41	1.58	1.74	1.91	2.06	2.20
0 8	3.10	2.29	1.46	.63	-.08	.02	.23	.45	.65	.85	1.05	1.24	1.43	1.62	1.82	2.01	2.20
0 9	3.20	2.28	1.33	.26	-1.33	-.43	-.04	.21	.43	.64	.85	1.06	1.28	1.50	1.73	1.96	2.20
0 10	3.20	2.27	1.33	.41	-.38	-.35	-.19	.01	.21	.42	.64	.88	1.12	1.38	1.64	1.91	2.20
0 11	3.30	2.29	1.32	.42	-.27	-.42	-.36	-.21	-.03	.19	.43	.68	.96	1.24	1.53	1.83	2.10
0 12	3.30	2.27	1.23	.20	-.67	-.72	-.62	-.47	-.29	-.07	.19	.47	.78	1.10	1.43	1.76	2.10
0 13	3.40	2.26	1.11	-.15	-1.92	-1.18	-.93	-.77	-.60	-.37	-.08	.23	.58	.94	1.32	1.70	2.10
0 14	3.40	2.26	1.11	-.01	-.99	-1.14	-1.14	-1.09	-.96	-.72	-.40	-.03	.36	.77	1.19	1.63	2.10
0 15	3.50	2.27	1.09	-.01	-.90	-1.27	-1.42	-1.49	-1.45	-1.15	-.75	-.32	.12	.58	1.05	1.52	2.00
0 16	3.50	2.23	.98	-.23	-1.32	-1.61	-1.80	-2.01	-2.19	-1.69	-1.15	-.63	-.13	.38	.90	1.41	1.90
0 17	3.40	2.15	.85	-.58	-2.55	-2.06	-2.16	-2.58	-3.62	-2.28	-1.52	-.93	-.39	.17	.75	1.33	1.90
0 18	3.40	2.12	.85	-.41	-1.56	-1.92	-2.20	-2.51	-2.77	-2.28	-1.73	-1.20	-.66	-.05	.59	1.24	1.90
0 19	3.30	2.08	.85	-.34	-1.35	-1.88	-2.23	-2.52	-2.66	-2.36	-1.93	-1.48	-.99	-.31	.42	1.15	1.90
0 20	3.30	2.05	.79	-.47	-1.63	-2.02	-2.33	-2.68	-2.99	-2.58	-2.14	-1.81	-1.53	-.63	.25	1.05	1.80
0 21	3.30	2.03	.74	-.69	-2.68	-2.23	-2.40	-2.91	-4.05	-2.82	-2.27	-2.11	-2.67	-.93	.15	1.01	1.80
0 22	3.20	2.03	.84	-.37	-1.49	-1.85	-2.15	-2.49	-2.80	-2.41	-1.99	-1.69	-1.44	-.57	.27	1.04	1.80
0 23	3.20	2.07	.94	-.14	-1.06	-1.53	-1.85	-2.12	-2.27	-2.01	-1.62	-1.23	-.81	-.20	.45	1.09	1.70
0 24	3.20	2.10	1.01	-.08	-1.09	-1.36	-1.59	-1.89	-2.17	-1.73	-1.25	-.81	-.37	.12	.65	1.17	1.70
0 25	3.10	2.10	1.08	-.10	-1.86	-1.24	-1.28	-1.69	-2.78	-1.51	-.86	-.39	.02	.42	.84	1.26	1.70
0 26	3.10	2.14	1.30	.46	-.33	-.46	-.59	-.82	-1.07	-.68	-.27	.08	.40	.71	1.02	1.32	1.60
0 27	2.70	2.08	1.50	.98	.54	.33	.19	.06	-.00	.14	.36	.58	.80	1.01	1.21	1.41	1.60
0 28	2.30	1.96	1.67	1.40	1.17	1.04	.95	.89	.85	.89	.99	1.09	1.20	1.30	1.40		

1.50 1.60
0 29 1.80 1.80 1.80 1.80 1.70 1.70 1.70 1.70 1.60 1.60 1.60 1.60 1.60 1.60 1.60
1.60 1.60

OHEAD WILL BE SAVED ON UNIT 30 AT END OF TIME STEP 1, STRESS PERIOD 1

1 DRAWDOWN IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
0 2	*****	8.69	7.50	6.10	4.42	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
0 3	*****	8.40	7.45	6.40	5.13	3.34	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
0 4	*****	8.19	7.48	6.78	6.04	4.31	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
0 5	*****	7.98	7.49	7.25	8.46	5.37	3.53	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
0 6	*****	7.70	7.33	7.02	6.71	5.43	3.94	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
0 7	*****	7.42	7.14	6.87	6.47	5.54	4.35	2.95	*****	*****	*****	*****	*****	*****	*****	*****	*****
0 8	*****	7.13	7.00	6.91	6.76	5.84	4.72	3.43	*****	*****	*****	*****	*****	*****	*****	*****	*****
0 9	*****	6.86	6.89	7.09	8.12	6.27	5.10	3.84	*****	*****	*****	*****	*****	*****	*****	*****	*****
0 10	*****	6.57	6.68	6.82	6.91	6.24	5.44	4.53	3.44	*****	*****	*****	*****	*****	*****	*****	*****
0 11	*****	6.31	6.49	6.67	6.73	6.36	5.82	5.21	4.51	3.62	*****	*****	*****	*****	*****	*****	*****
0 12	*****	6.05	6.38	6.73	7.07	6.69	6.26	5.92	5.62	4.65	3.63	*****	*****	*****	*****	*****	*****
0 13	*****	5.81	6.29	6.93	8.60	7.13	6.66	6.63	8.22	5.56	4.40	3.39	*****	*****	*****	*****	*****
0 14	*****	5.59	6.10	6.63	7.16	6.94	6.71	6.60	6.53	5.71	4.84	3.90	*****	*****	*****	*****	*****
0 15	*****	5.36	5.92	6.45	6.87	6.86	6.74	6.63	6.44	5.90	5.25	4.57	3.79	*****	*****	*****	*****
0 16	*****	5.13	5.78	6.45	7.10	6.99	6.85	6.79	6.76	6.21	5.67	5.20	4.77	3.92	*****	*****	*****
0 17	*****	4.87	5.65	6.60	8.69	7.25	6.96	7.04	7.82	6.57	6.00	5.74	6.27	4.49	*****	*****	*****
0 18	*****	4.56	5.39	6.19	6.95	6.90	6.83	6.85	6.90	6.47	6.06	5.74	5.42	4.51	3.44	*****	*****
0 19	*****	4.24	5.13	5.92	6.53	6.69	6.71	6.73	6.70	6.42	6.09	5.76	5.37	4.62	3.70	*****	*****
0 20	*****	3.94	4.93	5.83	6.66	6.68	6.66	6.73	6.84	6.49	6.15	5.90	5.64	4.83	3.95	3.06	*****
0 21	*****	3.66	4.75	5.89	8.31	6.79	6.61	6.81	7.70	6.60	6.18	6.07	6.65	5.05	4.06	3.21	*****
0 22	*****	3.40	4.43	5.36	6.21	6.25	6.29	6.41	6.57	6.26	5.97	5.77	5.56	4.80	3.96	3.07	*****
0 23	*****	3.18	4.11	4.93	5.57	5.81	5.94	6.05	6.12	5.94	5.72	5.50	5.22	4.58	3.77	*****	*****
0 24	*****	2.86	3.78	4.63	5.35	5.51	5.62	5.79	5.98	5.71	5.47	5.33	5.20	4.49	3.69	*****	*****
0 25	*****	2.11	3.36	4.38	5.82	5.25	5.26	5.54	6.50	5.47	5.13	5.14	6.00	4.44	3.55	*****	*****
0 26	*****	2.08	2.99	3.74	4.39	4.52	4.62	4.77	4.93	4.66	4.46	4.35	4.38	3.86	*****	*****	*****
0 27	*****	2.06	2.60	3.07	3.52	3.76	3.87	3.94	3.91	3.72	3.57	3.37	*****	*****	*****	*****	*****
0 28	*****	*****	*****	*****	2.75	2.99	3.08	3.09	2.93	*****	*****	*****	*****	*****	*****	*****	*****
0 29	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****

1 DRAWDOWN IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0 1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
0 2	.00	.14	.29	.41	.49	.49	.43	.38	.32	.27	.22	.18	.15	.11	.07	.03	.00
0 3	.00	.29	.58	.86	1.05	1.01	.89	.76	.65	.55	.45	.37	.29	.21	.14	.07	.00
0 4	.00	.44	.90	1.39	1.84	1.61	1.36	1.14	.96	.80	.67	.55	.43	.32	.21	.10	.00
0 5	.00	.56	1.18	1.97	3.32	2.26	1.78	1.48	1.25	1.06	.88	.72	.56	.42	.28	.14	.00
0 6	.00	.65	1.30	1.95	2.52	2.31	2.03	1.75	1.51	1.29	1.09	.89	.70	.53	.35	.17	.00
0 7	.00	.70	1.39	2.05	2.50	2.47	2.25	2.00	1.75	1.50	1.28	1.06	.84	.63	.41	.21	.00
0 8	.00	.78	1.55	2.32	2.96	2.80	2.52	2.24	1.98	1.72	1.46	1.21	.97	.73	.48	.24	.00
0 9	.00	.83	1.71	2.71	4.23	3.26	2.80	2.48	2.20	1.92	1.65	1.38	1.11	.83	.55	.28	.00
0 10	.00	.88	1.74	2.59	3.30	3.19	2.96	2.68	2.41	2.14	1.85	1.55	1.25	.94	.62	.31	.00
0 11	.00	.90	1.78	2.60	3.20	3.27	3.13	2.90	2.65	2.36	2.05	1.73	1.39	1.05	.71	.35	.00
0 12	.00	.95	1.90	2.84	3.61	3.58	3.39	3.16	2.90	2.61	2.28	1.93	1.55	1.17	.78	.40	.00
0 13	.00	1.01	2.05	3.20	4.87	4.04	3.70	3.45	3.20	2.89	2.53	2.15	1.73	1.31	.87	.44	.00
0 14	.00	1.03	2.06	3.07	3.94	4.00	3.90	3.76	3.55	3.23	2.83	2.39	1.93	1.45	.97	.49	.00
0 15	.00	1.05	2.09	3.07	3.85	4.11	4.17	4.15	4.02	3.64	3.16	2.65	2.14	1.61	1.08	.54	.00
0 16	.00	1.09	2.20	3.28	4.25	4.44	4.53	4.64	4.74	4.15	3.53	2.93	2.36	1.78	1.19	.60	.00
0 17	.00	1.13	2.30	3.61	5.46	4.86	4.86	5.19	6.14	4.71	3.87	3.20	2.59	1.96	1.30	.65	.00
0 18	.00	1.13	2.27	3.40	4.44	4.69	4.87	5.08	5.25	4.68	4.05	3.44	2.82	2.14	1.43	.72	.00
0 19	.00	1.12	2.23	3.29	4.19	4.61	4.86	5.05	5.10	4.72	4.21	3.68	3.12	2.37	1.57	.78	.00
0 20	.00	1.12	2.24	3.38	4.42	4.70	4.91	5.16	5.38	4.89	4.37	3.97	3.62	2.65	1.70	.84	.00
0 21	.00	1.10	2.25	3.55	5.42	4.85	4.92	5.34	6.39	5.08	4.45	4.22	4.71	2.91	1.77	.85	.00
0 22	.00	1.04	2.09	3.16	4.16	4.41	4.61	4.85	5.08	4.61	4.12	3.75	3.44	2.51	1.61	.79	.00
0 23	.00	.96	1.93	2.86	3.65	4.01	4.23	4.41	4.48	4.15	3.69	3.24	2.76	2.09	1.38	.69	.00
0 24	.00	.87	1.78	2.71	3.59	3.75	3.88	4.10	4.30	3.79	3.25	2.76	2.26	1.72	1.14	.58	.00
0 25	.00	.77	1.59	2.62	4.25	3.52	3.47	3.80	4.83	3.50	2.79	2.27	1.82	1.37	.91	.46	.00
0 26	.00	.60	1.23	1.91	2.58	2.62	2.67	2.83	3.02	2.58	2.13	1.73	1.38	1.03	.69	.34	.00
0 27	.00	.40	.82	1.31	1.55	1.69	1.77	1.84	1.85	1.67	1.41	1.16	.92	.68	.46	.23	.00
0 28	.00	.20	.40	.59	.74	.83	.88	.90	.89	.82	.70	.58	.46	.35	.23	.12	.00
0 29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

ODRAWDOWN WILL BE SAVED ON UNIT 40 AT END OF TIME STEP 1, STRESS PERIOD 1

0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 1

0 CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.60428E+06	STORAGE =	1633.2
CONSTANT HEAD =	.69820E+06	CONSTANT HEAD =	1887.0
WELLS =	.00000	WELLS =	.00000
0 TOTAL IN =	.13025E+07	TOTAL IN =	3520.2
0 OUT:		OUT:	

```
                 STORAGE =      .00000                                                   STORAGE =      .00000
           CONSTANT HEAD =     2444.3                                              CONSTANT HEAD =     6.6061
                   WELLS =     .13000E+07                                                  WELLS =     3513.6
0              TOTAL OUT =     .13025E+07                                              TOTAL OUT =     3520.2
0               IN - OUT =    -2.5000                                                   IN - OUT =    -.70801E-02
0     PERCENT DISCREPANCY =                 .00                               PERCENT DISCREPANCY =                 .00

0

      TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD  1
                                 SECONDS       MINUTES        HOURS          DAYS           YEARS
                          ---------------------------------------------------------------------------
     TIME STEP LENGTH         .319680E+08    532800.       8880.00        370.000        1.01300
   STRESS PERIOD TIME         .319680E+08    532800.       8880.00        370.000        1.01300
TOTAL SIMULATION TIME         .319680E+08    532800.       8880.00        370.000        1.01300
1
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